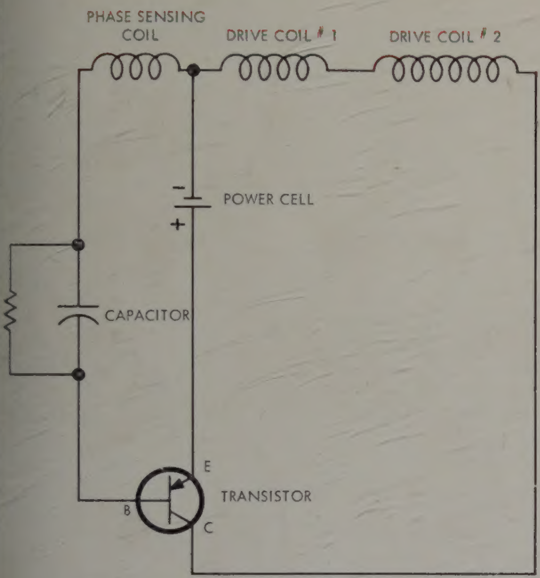
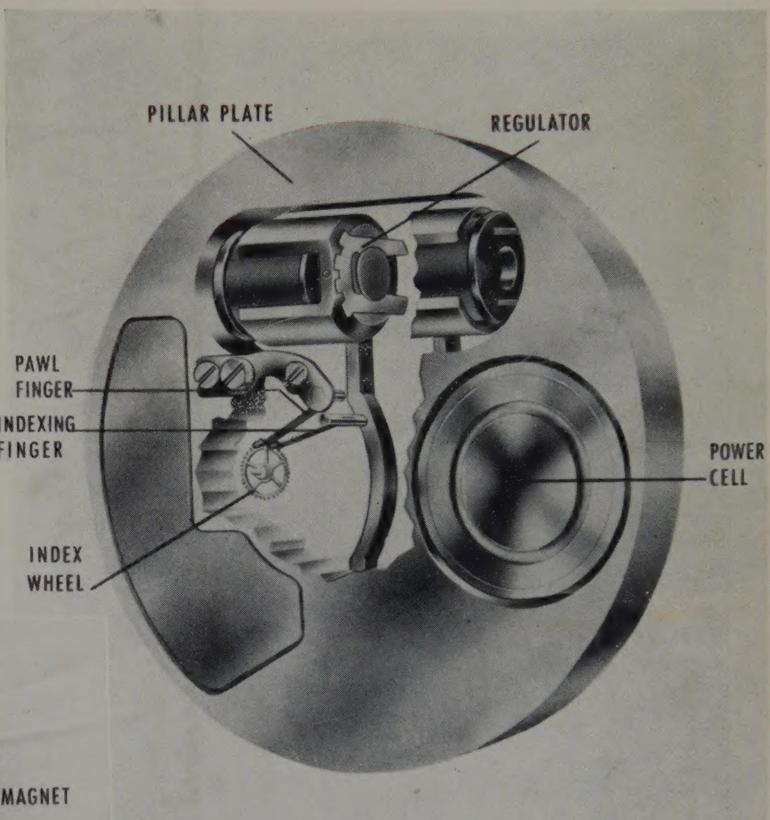
November 1960

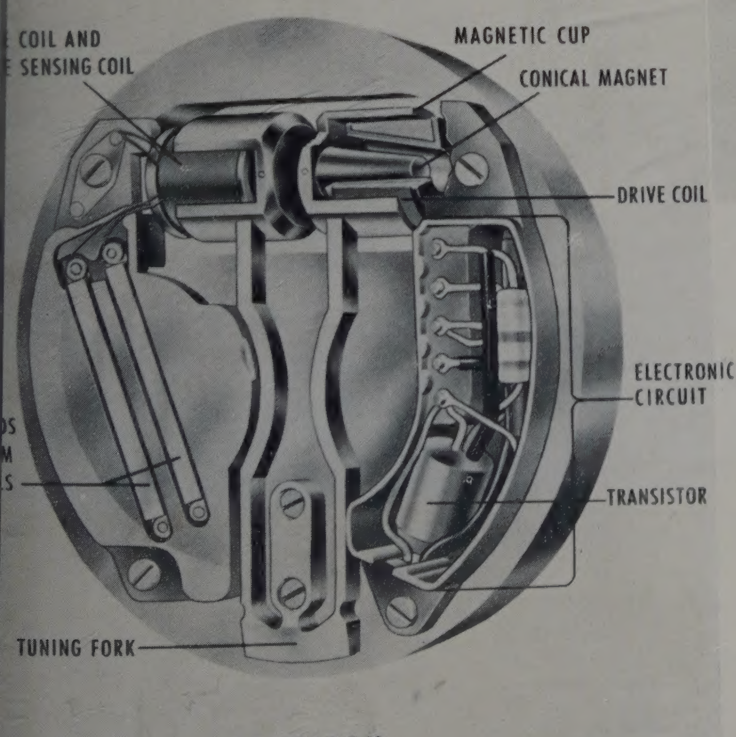
75¢

EMICONDUCTOR PRODUCTS





ACCUTRON
BASIC MECHANISM
TRAIN SIDE



ACCUTRON
BASIC MECHANISM
DIAL SIDE

TRANSISTORIZED TIMEPIECE

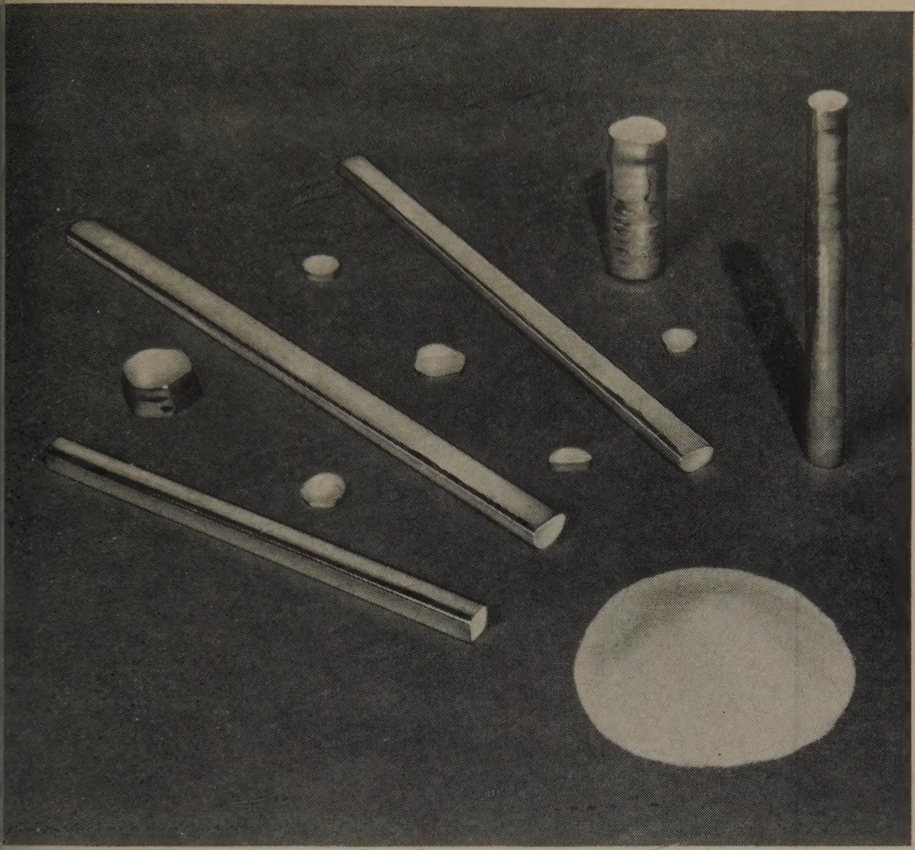
Thermal Evaluation of Microminiaturized Equipment

High Accuracy Expanded Scale Meter Using Zener Diodes

Flow Graph Analysis

Circle No. 1 on Reader Service Card

Germanium *and other semiconductors from* **EAGLE-PICHER**



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GERMANIUM DIOXIDE, minimum purity 99.999%.

FIRST REDUCTION GERMANIUM METAL, minimum resistivity 5 ohm-cm.

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Metallic crystals, minimum purity 99.9999%.
Metallic crystals, minimum purity 99.999%.

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

November 1960 Vol. 3 No. 11

CONTENTS

SEMICONDUCTOR PRODUCTS assumes no responsibility for company credit affiliations claimed by authors for byline purposes.

Front Cover

Line drawings of "ACCUTRON" show principal components of unique electronic timepiece created by Bulova Watch Company, Inc. Drawing at left shows dial side of movement with tuning fork assembly in center including a cutaway of one coil showing one of the conical magnets and (at right) the basic elements of the electronic circuit. Drawing at right shows rear of the mechanism with simplified drawing of indexing components, the power cell in its recess, and one of the two regulators that are used by a jeweler to change the frequency of the tuning fork. Electronic circuit acts as an on-off switch as it continuously imparts driving pulses through the drive coils to the magnetic cup arrangement on each tine of the tuning fork time standard (not shown). Voltage flows from the power cell to drive coils through switching germanium transistor when the phase-sensing coil "senses" the correct position of the tuning fork during each vibration. Frequency of vibration is maintained at 360 cycles per second. The 1.3-volt mercury power cell delivers 6 millionths of an ampere (0.000006), 8 millionths of a watt (0.000008).

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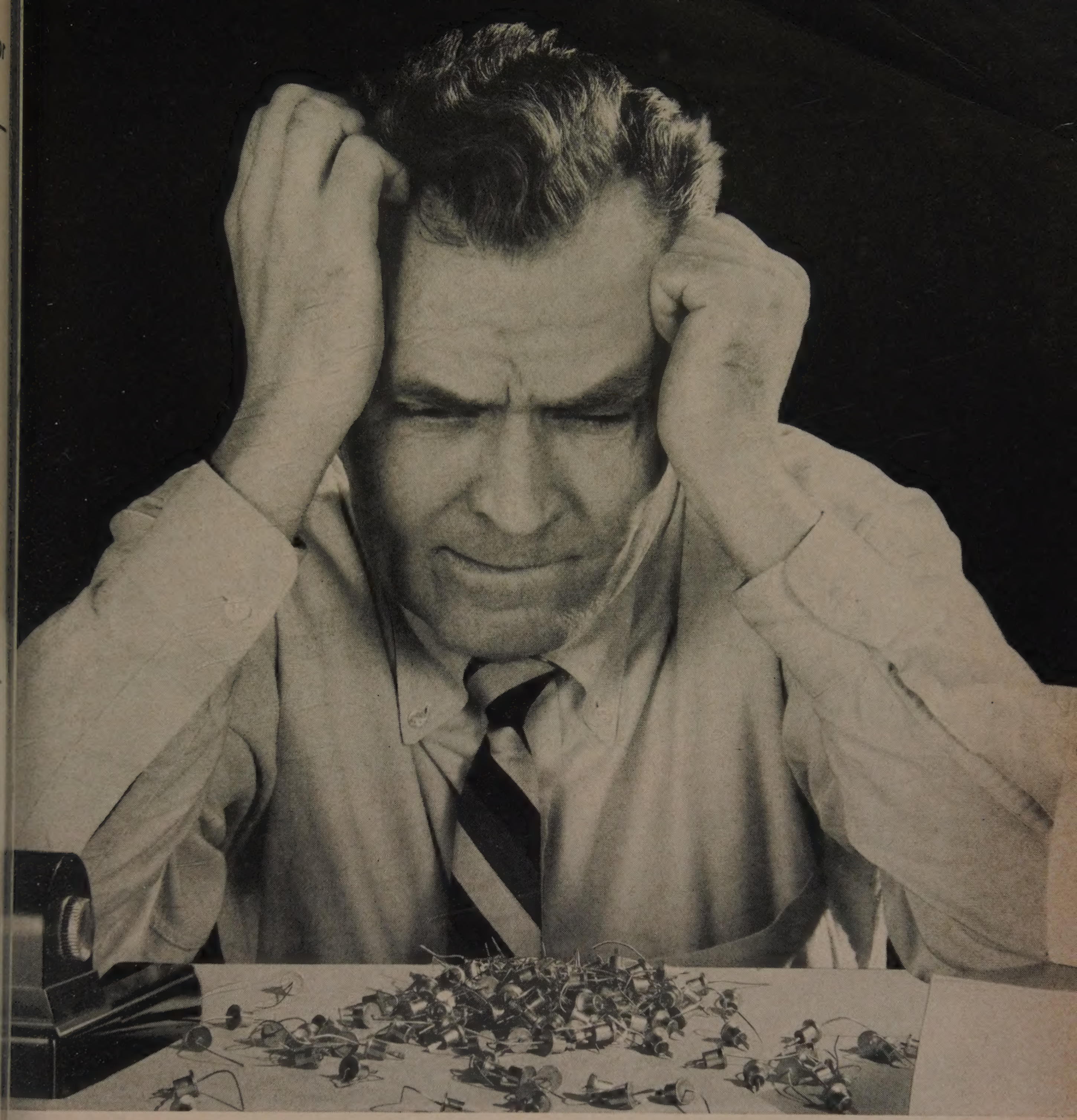
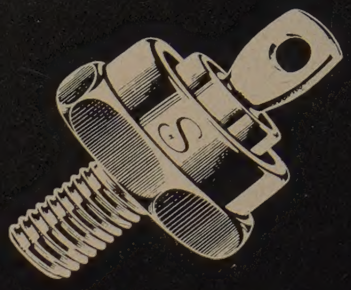
POSTMASTER: SEND FORM 3579 to SEMICONDUCTOR PRODUCTS, 300 West 43rd STREET, NEW YORK 36, N. Y.



In Answer to the Ad that Started it all...



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An outstanding illustration of SRC quality, reliability and safety is found in its 35 ampere silicon power rectifiers. For example, these hermetically sealed diodes are so conservatively rated that they will withstand **1200 ampere** surges!*

These silicon rectifiers are nominally rated at 35 amperes and are available in a range of 50 to 600 volts. Readily interchangeable with standard existing 35 ampere units, this entire premium rectifier series is now available for immediate delivery at no premium in price!

For further detailed information and technical data send today for your free copy of the new SRC Silicon Rectifier Handbook and Catalog covering the full line up through 400 ampere units.

*As substantiated by United Testing Laboratories

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STANDARD RECTIFIER CORP.

620 East Dyer Road, Santa Ana, California • Kimberly 5-8241

In August, the Standard Rectifier Corporation launched its national advertising campaign. The original ad of this new series is shown reproduced above. The response it has enjoyed, since initially appearing in the electronic trade journals, has been tremendous! It has resulted in literally hundreds of requests for further information.

The Standard Rectifier Corporation is fully aware of the need... indeed the demand of industry for electronic components that embody greater factors of *safety* and *reliability*. To further substantiate those claims made in reference to the quality of our products, we have listed below a few of the more important reasons why an ever-increasing number of engineers are specifying SRC!

1. SRC uses an aluminum-silicon junction substantially larger in area than industry standards. SRC's "planer" type construction extends the area of contact across the entire silicon chip.
   BENEFIT: Nearly twice the one-surge rating of competitive products! More efficient heat dissipation... longer life.

2. Every SRC rectifier product is completely production tested and inspected by the use of oscilloscope sweeping techniques at 100 volts above, or two times rated PIV, whichever is smaller.
   BENEFIT: Far greater transient protection.

3. Another plus feature of SRC's unique type of construction is its newly-developed method of utilizing nickel-coated molybdenum discs in their "floating" contact design... this results in a nearly perfect bonding of materials.
   BENEFIT: Less thermal fatigue aging.

4. SRC extensively tests its rectifiers for current surge ratings. Example: The 35 amp series is tested at 350 amps for two seconds. Independent lab tests show it will safely handle eight milli-second pulses up to 1200 amperes!*
   BENEFIT: Better overload and surge protection, thus resulting in more effective fuse protection.

In the coming months our ads will serve to introduce many new and exciting products... the results of Standard's research and development. We hope you will watch for them, and we invite your inquiries.

**As substantiated by the United Testing Laboratories*

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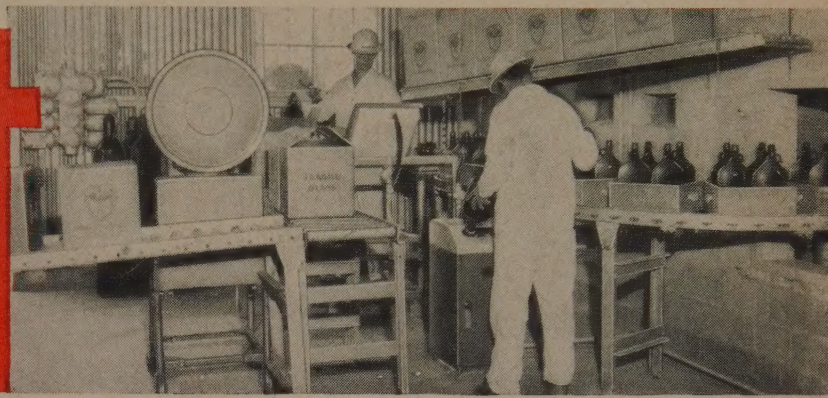
East

Marcus Hook, Pa.

West



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B&A® assures fast, dependable supply of highest-purity "Electronic-Grade" chemicals

Wherever *your* electronics plant is located, you're close to a source of Baker & Adamson "Electronic-Grade" chemicals—the nation's highest-quality line. B&A production facilities at Chicago, Ill., El Segundo, Calif., Marcus Hook, Pa., and Nichols, California, plus 24 stock points across the nation assure *same or next day delivery* in most major electronics centers.

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B&A controls impurities in "Electronic-Grade" chemicals to a degree surpassing all previous standards! Highest purity is assured through rigorous methods of chemical and instrument analysis, and in the case of solvents is supplemented by resistivity measurements . . . a technique introduced by Baker & Adamson scientists to detect and determine trace impurities.

Our free booklet, "B&A Electronic Chemicals," includes a listing of products with specifications and uses. Write today, on company letterhead please, for your copy.

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GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

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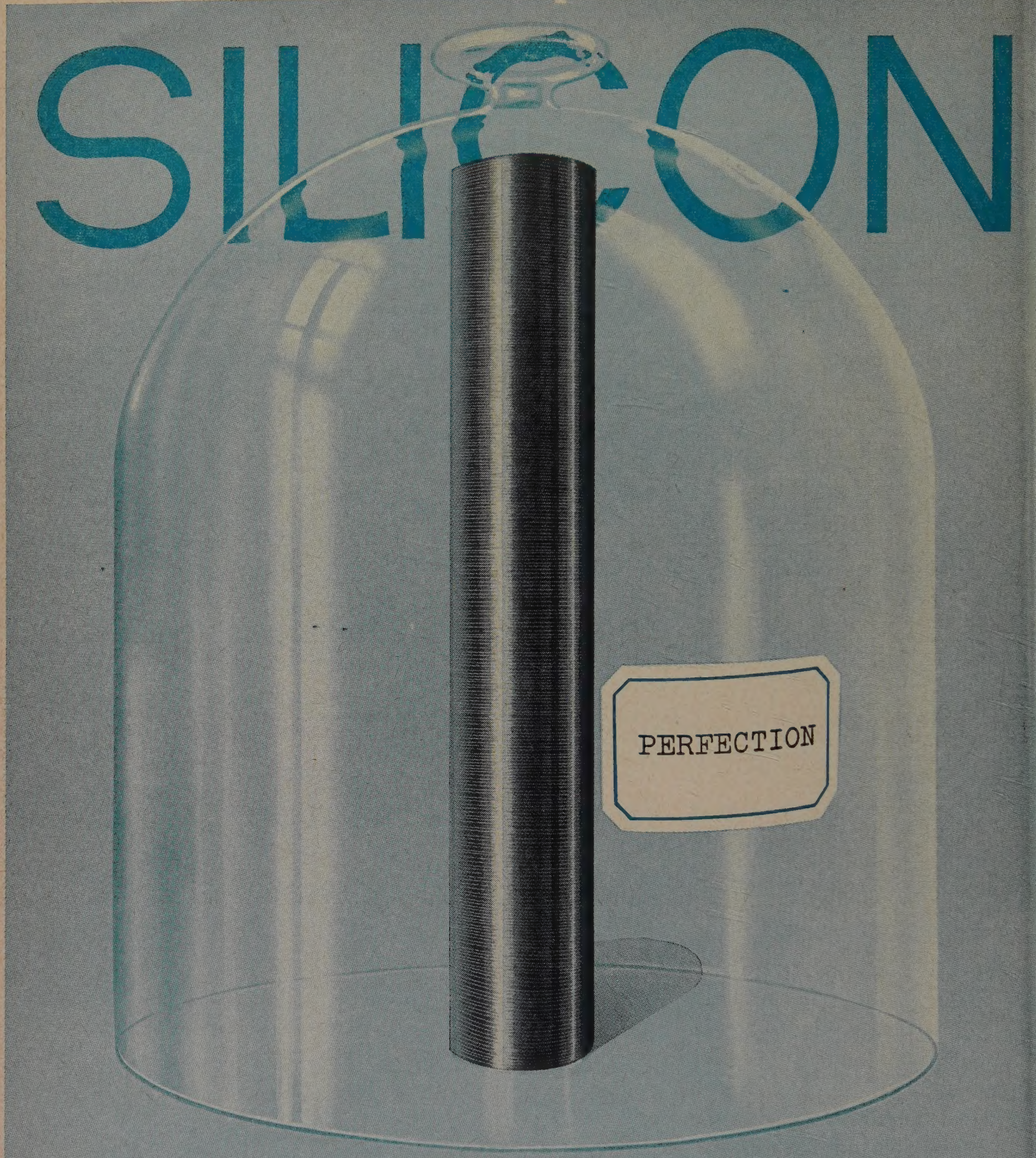

AT GRACE ELECTRONICS the pledge of high quality Silicon meeting your specifications is not a promise without meaning. The reason: Perfection is *standard* at Grace!

The fact that nothing is left to chance means greater yields per pound from Grace Silicon. Impurity levels are kept to a minimum throughout the process, resulting in bulk and monocrystalline silicon with boron content as low as 0.1 ppb. This means minimum compensation and therefore superior device characteristics for you.

Grace Silicon is available in all grades and forms. Bulk: Grades I, II and III; P and N type. Grace Float Zone and Czochralski monocrystals from 0.1 to 1000 ohm-cm. Polycrystalline rods. Monocrystalline slices. Write today for details.

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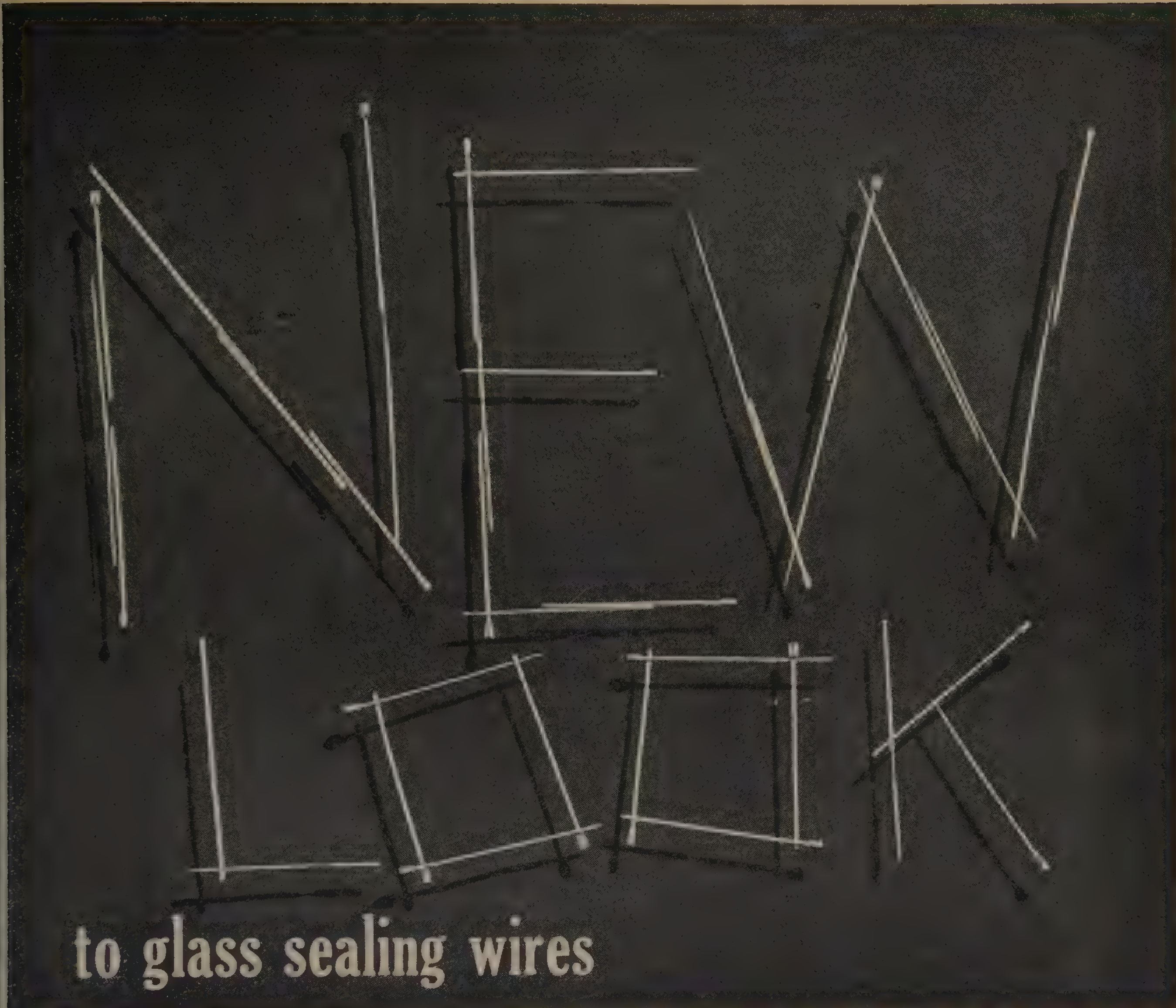
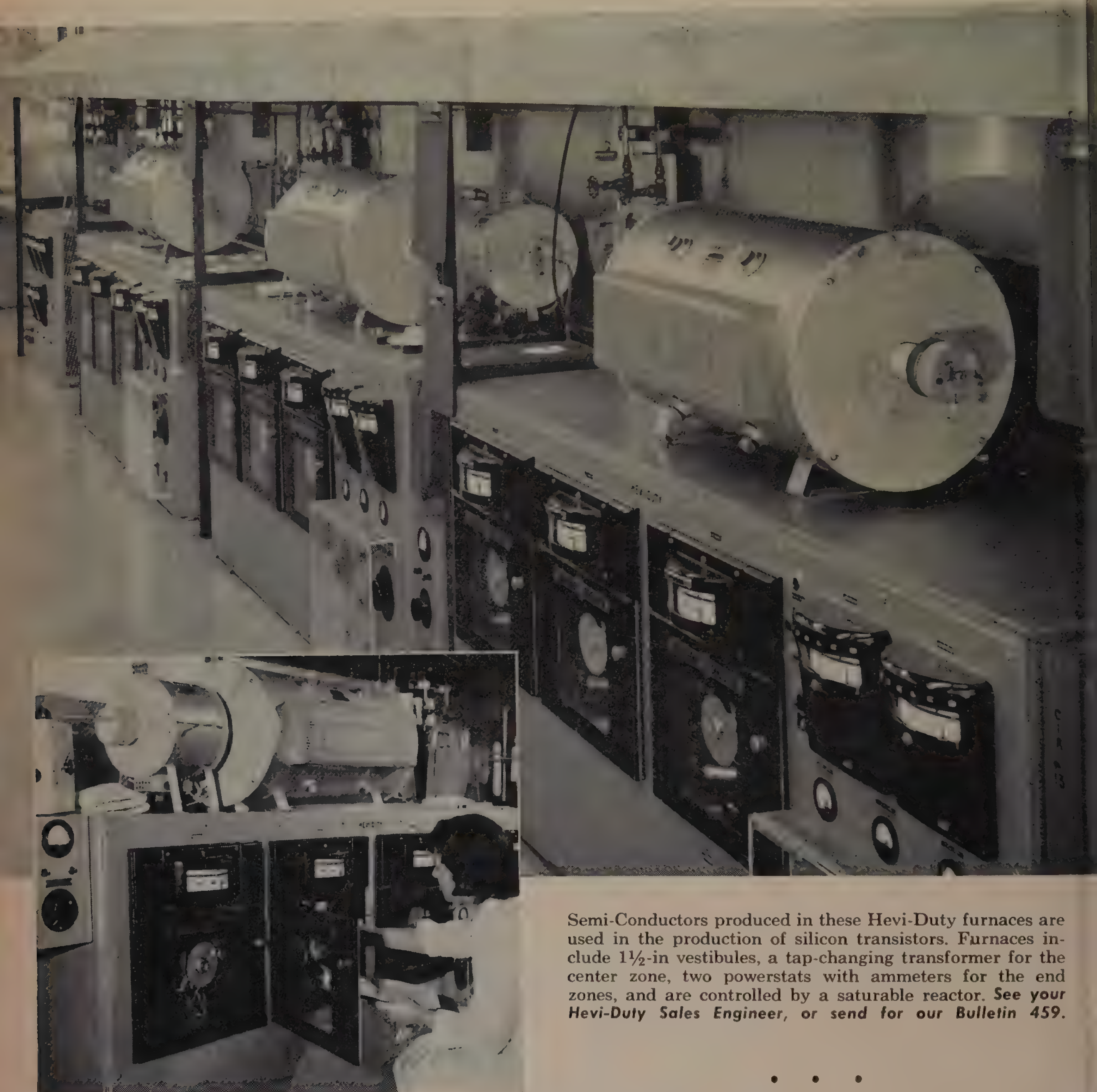

NEW
LOOK
to glass sealing wires

Only Hevi-Duty Furnaces Meet Rigid Reliability Standards of Pacific Semiconductors, Inc.



Semi-Conductors produced in these Hevi-Duty furnaces are used in the production of silicon transistors. Furnaces include 1½-in vestibules, a tap-changing transformer for the center zone, two powerstats with ammeters for the end zones, and are controlled by a saturable reactor. ***See your Hevi-Duty Sales Engineer, or send for our Bulletin 459.***

• • •

To meet rigid reliability standards, Hevi-Duty globar tube-type furnaces were selected by PSI because of their tight temperature uniformity.

In the PSI Transistor Plant, at Lawndale, California, Hevi-Duty tube furnaces are used for silicon wafer diffusion at temperatures above 1200° C. During round-the-clock operation, the Hevi-Duty furnaces hold to ± 4° C over a 16-in. length within each 28-in. heating chamber . . . and to ± 1° C over a 10-in. length.

In addition to tight uniformity, Pacific Semiconductors, Inc., finds Hevi-Duty furnaces very easy to set up and load. Another important advantage is their ease of servicing. In one instance, PSI replaced a globar element while the furnace was operating at full temperature. The entire job took only 15 minutes and there were no detrimental effects on the load.

Find out how the right Hevi-Duty furnace can bring you production efficiency and laboratory accuracy.

HEVI-DUTY

A DIVISION OF B P C – A Division of Basic Products Corporation

Hevi-Duty Electric Company, Watertown, Wis.

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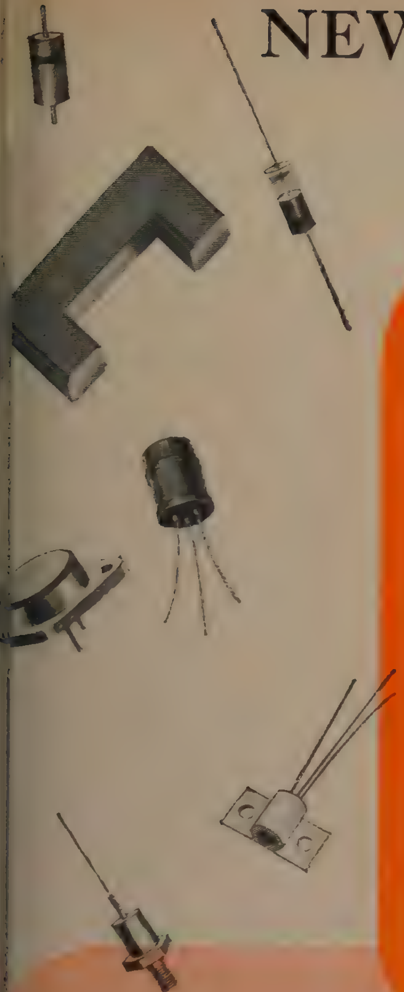
NEW Electronic Chemicals Brochure for manufacturers of



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electronic tubes
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Cadmium Nitrate
Cadmium Sulfate
Calcium Carbonate
Calcium Chloride
Calcium Fluoride
Calcium Nitrate
Calcium Phosphate
Carbon Tetrachloride
Cobalt Carbonate
Cobalt Oxide
Cobalt Nitrate
Ether, Anhydrous
Hydrochloric Acid
Hydrofluoric Acid
Hydrogen Peroxide, 30% and 3% Solution
Lithium Carbonate
Lithium Chloride
Lithium Nitrate
Lithium Sulfate
Magnesium Carbonate
Magnesium Chloride
Magnesium Oxide
Manganese Dioxide
Manganese Nitrate
Manganese Sesquioxide
Manganous Carbonate
Methanol
Nickel Carbonate
Nickel Oxide, Black
Nickel Oxide, Green
Nickelous Chloride
Nickelous Nitrate
Nickelous Sulfate
Nitric Acid
Petroleum Ether
Potassium Dichromate
Potassium Hydroxide
iso-Propyl Alcohol
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Sodium Carbonate
Sodium Chloride
Sodium Hydroxide
Sodium Phosphate Dibasic
Strontium Carbonate
Strontium Nitrate
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Toluene
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Zinc Nitrate
Zinc Oxide

ELECTRONIC CHEMICALS OF DEFINED PURITY
'Baker Analyzed' *Reagents*

This new brochure . . . just off the press . . . tells you how Baker Electronic Chemicals can help you achieve operating economies.

The Electronic Chemicals listed on the left bring you these benefits:

1. Highest purity defined to meet your critical electronic manufacturing needs.
2. Purity is proved — the 'Baker Analyzed' Reagent label shows the actual lot analysis.
3. Prices are economical for electronic processing use.
4. Deliveries are fast in each marketing area.

Write for your copy of "Electronic Chemicals of Defined Purity." Address J. T. Baker Chemical Co., Phillipsburg, New Jersey, Department SC-9.

J. T. Baker Chemical Co.
Phillipsburg, New Jersey

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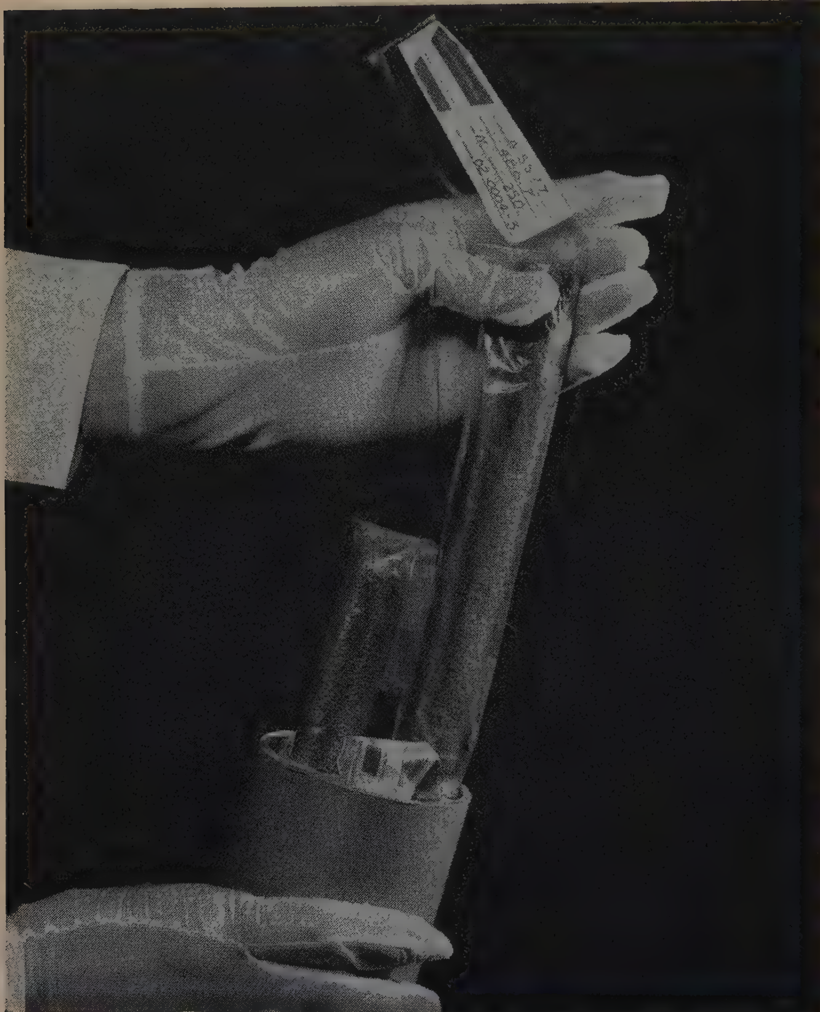
SILICON NEWS from Dow Corning

(PART 1)

The Untouchables

Hyper-Pure Silicon... Silicon So Pure Just a Touch Contaminates Its Quality



The highest purity attained in any element refined by man . . . purer than any element found in nature! That's Hyper-Pure Silicon.

With less than one part per billion of boron, Dow Corning Silicon is so pure that just the touch of a finger tip causes contamination — destroys its high quality.

To assure this untouchable purity when you receive them, Dow Corning polycrystalline rods are wrapped in special unbleached cellophane and sealed in airtight polyethylene envelopes.

Purity pays off in quality — in uniformity of properties . . . in relatively flat resistivity and lifetime profiles for the entire length of single crystal silicon grown from Dow Corning polycrystalline rod and chunk . . . in maximum yield.

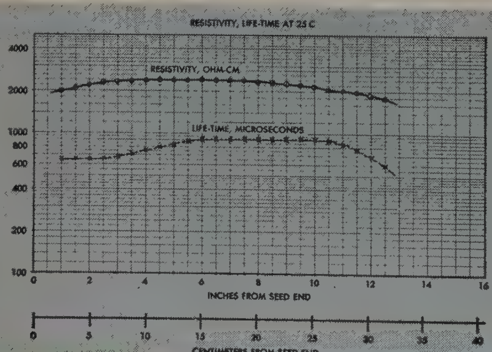
Specify polycrystalline rod if you use the zone refining process for conversion to single crystal — polycrystalline chunk if the Czochralski method is used. Both are of the same high quality.

Why is Dow Corning able to supply this untouchable quality?

Dow Corning has nearly twenty years experience in the production and purification of trichlorosilane, a chemical basic to both *Silicones* and *Hyper-Pure Silicon*. This experience, plus a fully integrated production facility, assures uniformly high quality — minimizes batch to batch variations.

For more information contact our nearest regional office, or write direct.

Typical properties of Dow Corning polycrystalline silicon, together with resistivity and life-time curves for an evaluation crystal, are shown below.



Typical Properties of Polycrystalline Silicon

Acceptor Impurity Content:	0.15 part/billion
Donor Impurity Content:	0.5 part/billion
Rod Diameter:	up to 26 mm (1.0 in.)
Rod Length:	up to 450 mm (17.7 in.)
Resistivity (vacuum zoned evaluation crystal):	>1000 ohm cm
Lifetime (vacuum zoned evaluation crystal):	>400 micro sec.

Free brochure — "Hyper-Pure Silicon for Semiconductor Devices." Write Dept. 8211.

HYPER-PURE SILICON DIVISION
Address: HEMLOCK, MICHIGAN

Dow Corning CORPORATION

MIDLAND, MICHIGAN

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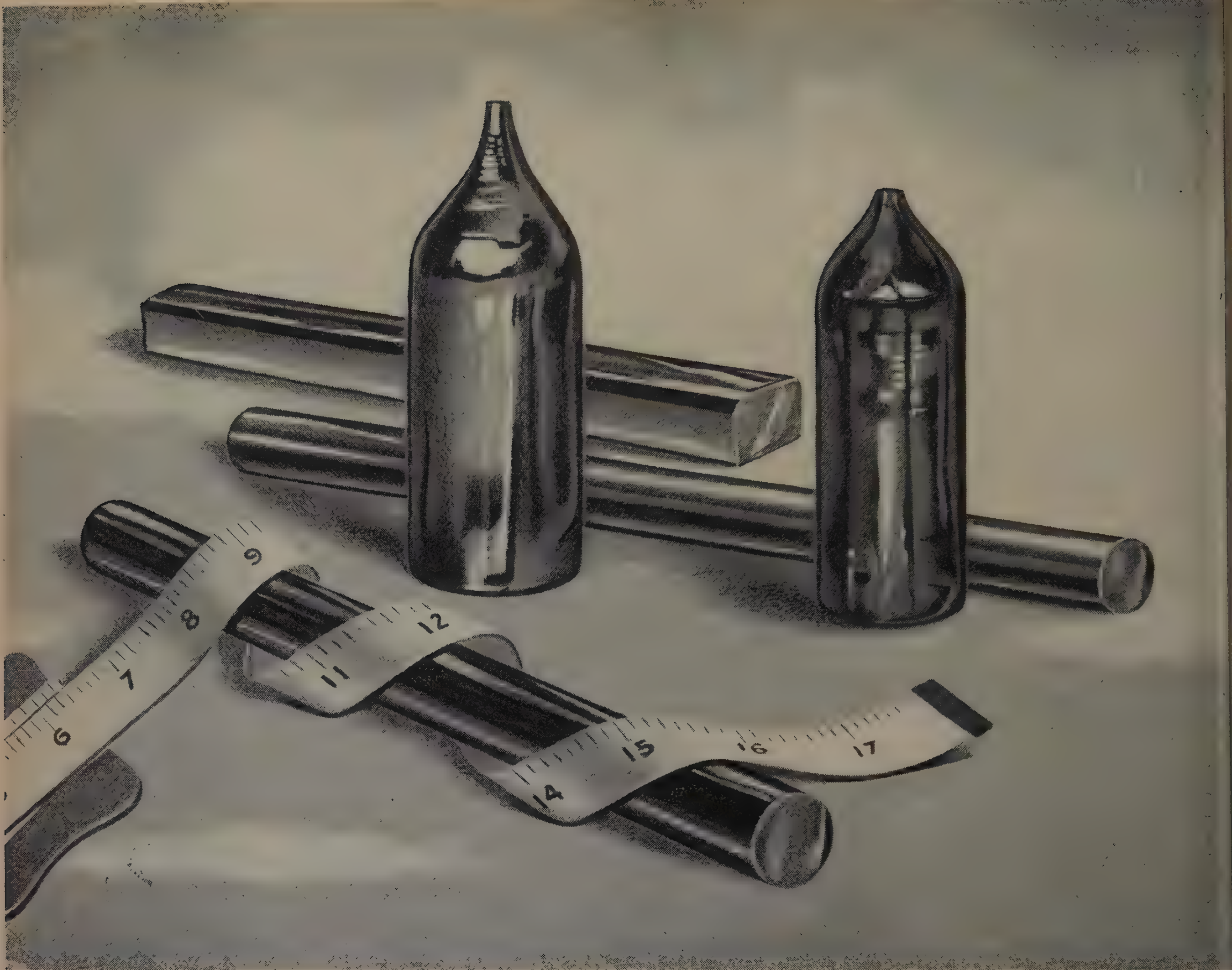

Now! Tailored to your budget!

Sylvania offers Germanium and Silicon Single Crystals in Production Quantities—at Attractive Prices

Now Sylvania offers to all device manufacturers the advantages of quantity production in the highly specialized field of germanium and silicon single crystals. These crystals are available at competitive prices and to desired specifications. Through the use of stringent quality-control techniques, you are assured of top-quality material—ready to use!

By specifying Sylvania crystals, you save the capital needed to invest in your own crystal-growing equipment. You save valuable space, time and technical manpower, too.

Another step in the Sylvania program to offer semiconductor materials and services to the device manufacturer is the completeness of product line. Sylvania now supplies germanium dioxide, intrinsic polycrystalline germanium, and doped germanium single crystals and slices. Polycrystalline silicon and doped silicon single crystals and slices are also available. To the germanium device manufacturer we can also offer our scrap-refining facilities.

For full details, a price on your quantity needs, plus your copy of a report on measuring and evaluating crystals for many specifications, write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pennsylvania.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

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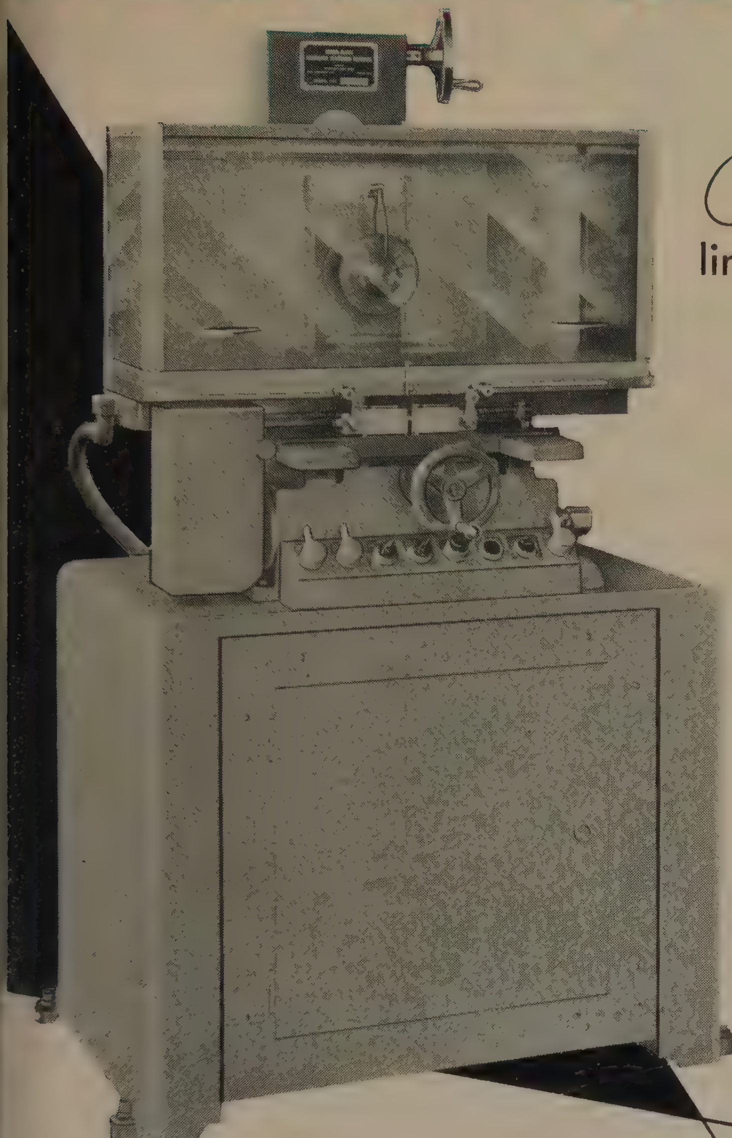

with Model WMA-2 —
the latest addition to the

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line of mechanical and hydraulic
wafering machines

New hydraulic system gives faster indexing cycle — ups production!

Now you can eliminate costly rejects, speed production and obtain exceptional indexing accuracy on your precision wafering operations on semiconductors and all difficult-to-cut materials.

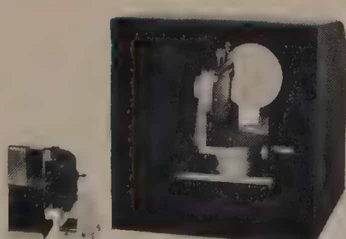
The new, highly efficient Micro-Matic Model WMA-2 precision wafering machine assures continued accuracy with minimum maintenance — speeds and simplifies wafering operations!

Check these outstanding advantages against *your manufacturing requirements . . .*

- Faster indexing cycle provides increased production.
- Indexing accuracy of ±.0001 permits greater precision.
- Infinitely variable indexing increments provide for parallel slices with a wide range of thicknesses up to .400″
- New, simplified push-button control incorporates automatic and semi-automatic cycling for both production and lab work.
- Table-travel adjustment is conveniently located at the front of the machine.

FOR QUALITY CONTROL —
Micromech Optical Orientation System

This easy-to-operate system produces accurate visual patterns for identification of principal planes of any single crystal material. No interpretation or correlation data needed. Operator need not be technically trained. Transference of aligned crystal from orientation base to wafering machine table allows accurate cutting of crystal on plane to which it was aligned. Self-contained, low-cost unit requires only 2 sq. ft. of table space.



Micromech Diamond Wheels

available in all popular and odd sizes —
Precision manufacture to extremely close tolerances assures accuracy of cut and long service. Both D1T (straight side) and D1TRS (relieved side) types furnished.

Send for free technical data without obligation.

MICROMECH MANUFACTURING CORP.

A Division of Sanford Manufacturing Corp.

1020 Commerce Avenue Union, New Jersey MUrdock 8-6323

Circle No. 19 on Reader Service Card

Market News . . .

Prices

Rheem Semiconductor Corp., Mountain View, California has announced the availability of developmental samples of silicon epitaxial transistors. Their RT409 is available at $170 each in maximum quantities of 10 units.

Philco Corp. has released a new high speed germanium transistor, *MADT* 2N779 in a TO-18 case. The price is $5.35 each in quantities of 1000 or more.

Sylvania Electric Products, Inc. is now marketing an audio frequency *p-n-p* germanium alloy transistor which meets MIL-S-19500B specifications. In quantities of 1-99 and 100-999 type 2N650 is $1.88 and $1.25; the 2N651 is $2.10 and $1.40; and the 2N652 is $2.49 and $1.60 each respectively.

Ovitron Corp. Long Island City, N.Y. has added two models to its line of silicon controlled rectifier triggers. Type 3A12 is priced at $35 and type 3A22 at $65 each.

Vitro Chemical Company is cutting the price of scandium oxide by almost 50% but in ultra-pure form the cost is still $2,850 a pound. The old price was $5,500.

Expansions

Dickson Electronic Corp., Scottsdale, Ariz. has purchased a 5 acre tract between Mesa and Tempe for the construction of an 80,000 square foot plant costing $640,000, for the manufacture of silicon Zener diodes and other products in the field of solid state electronics.

IBM plans to construct a two-story, 150,000 sq. ft. product development laboratory in Poughkeepsie, N.Y.

Hughes International Inc. has recently opened their 25,000 sq. ft. semiconductor plant in Glenrothes, Scotland. The company plans to manufacture silicon and germanium diodes, silicon rectifiers and transistors for the United Kingdom, European Free Trade Area and Commonwealth markets.

Texas Instruments Incorporated has announced that it is establishing a new subsidiary company, Texas Instruments France, to manufacture semiconductor devices and components in France for the European Common Market. The new French subsidiary company will manufacture a full line of silicon and germanium transistors, silicon diodes and rectifiers such as the company already produces at Dallas, Texas and Bedford, England.

Financial

Both Avnet Electronics Corporation (Westbury, L. I. and Los Angeles) and British Industries, Inc. (Port Washington, L. I.) have announced that the Board of Directors of both companies have approved in principle the merger of British Industries into Avnet.

Solitron Devices Inc., White Plains, N. Y. plans public sale of $400,000 of debentures. Proceeds will be used to lease and move to a new plant as well as to purchase additional equipment.

Avnet Electronics Corporation has announced net sales for the fiscal year ended June 30, 1960 of $9,271,181 compared with net sales of $6,372,595 for the previous fiscal year, an increase of 45%. Net income totalled $1,014,051, or sixty-seven cents per share on 1,513,300 shares outstanding as of June 30, 1960. This represents an increase of 32% in earnings over fiscal 1959 when net income totalled $767,620 or fifty-five cents per share on 1,400,000 shares then outstanding after giving effect to the two for one split which occurred in May, 1960.

Tang Industries, Inc. has announced the acquisition of Integron, Inc., Waltham, Mass., a manufacturing, consulting, and R. & D. firm. In addition to Systems and Instrumentation, Engineering Services, a Semiconductor group will be formed to offer consulting service to the Semiconductor Industry.

New Firms

Espey Manufacturing and Electronics Corporation of Saratoga Springs, New York has established a new division for the manufacture and marketing of semiconductor products. It is to be called the Saratoga Semiconductor Division.

Computer Diode Corp. of Lodi, N. J. has recently been organized. The firm is producing both conventional and specialty silicon glass diodes.

Sales

Rheem Semiconductor Corporation has announced the opening of a new sales office located at 320 Northern Boulevard, Great Neck, L. I., New York. Rheem's distributor on Long Island is Arrow Electronics Inc., located in Mineola, L. I., New York. The firm also has sales offices in Englewood, New Jersey, Minneapolis, Chicago, Detroit, Los Angeles, Lexington, Massachusetts, Riverdale, Maryland, Lemon Grove, California, and Mountain View, California.

The Semiconductor division of Syntron Co. has named McDowell-Redlingshafer Sales Co. St. Louis, Mo. as their sales representative for the Central States area.

The Semiconductor division of General Instrument Corp. has expanded its sales-marketing program by adding factory sales offices in Boston, Washington, San Francisco, San Diego, and Phoenix.

Factory sales in July of transistors were off sharply from June levels, according to the Electronic Industries Association. EIA reported 7,070,884 units, valued at $18,083,802 were sold in July. This was 3,321,528 units and $9,257,931 under June sales.

January-July sales this year continued well ahead of January-July 1959 sales—67,556,567 units, at $171,017,763, against 42,128,291 units at $115,432,090.

Electronic Transistors Corp., North Bergen, New Jersey, manufacturers of the recently developed Multi-Head Transistor (Multisistor) has announced that it

(Continued on page 20)

Market News

(from page 18)

will produce a complete line of over 100 different transistor types made especially for replacement of faulty transistors in Japanese-made radios.

Hull Corporation, Hatboro, Pennsylvania, manufacturers of vacuum furnaces, freeze dryers, impregnators, potters, resin handling systems, and molding presses, has opened a Cleveland office providing sales and service engineering over Ohio, Eastern Michigan, Western Pennsylvania, Southern Indiana, Ohio, Kentucky, and West Virginia.

Suppliers

Standard Kollsman Industries, Inc. has announced the formation of a new subsidiary—Kollstan Semiconductor Elements Inc. at Golden, Colo. Kollstan will produce basic material forms used in the manufacture of transistors, diodes, rectifiers and other semiconductor devices. The firm is now manufacturing highly-advanced crystal element subassemblies for semiconductor manufacturers, and is producing its own silicon crystals. It is also supplying finished slices and wafers to manufacturers' specific electrical and mechanical requirements.

Distributors

Newark Electronics Corp. and Allied Radio Corp. are stocking diodes and rectifiers from Texas Instruments Inc. under the firm's new policy of price protection on these items up to 4,999 pieces.

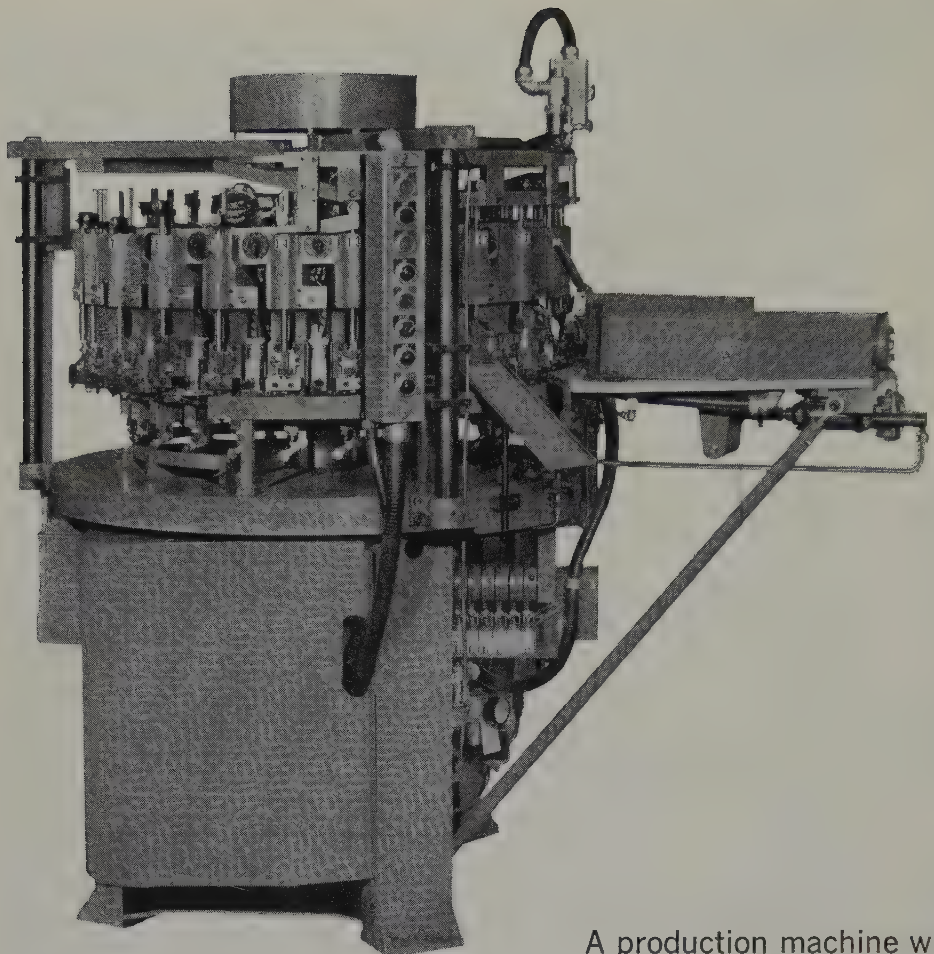
Fairchild Semiconductor has appointed three additional distributors for their silicon transistors and diodes. These are Almac Electronics Corporation in Seattle, Wash. for the Northwest area and Denny-Hamilton Electronics in San Diego for the Southern California area. Ward Terry and Company's Electronic Parts Division in Denver will have the franchise for the mountain states area.

Contracts

Hughes Aircraft Company's semiconductor division has received a U.S. Army Signal Corps contract of $150,000 for advanced research on tunnel diodes. Investigations will be made on the effect of heavily-doped junctions on the tunnel effect and the effects of various materials on the diode performance. The firm expects to extend the study program well beyond the amount awarded by the contract, with the remaining costs financed by the company.

American Avionics, Inc. a division of Astro-Science Corporation, Los Angeles electronics manufacturer, has announced the receipt of contracts for solid-state power supplies totalling approximately $100,000.

A $52,990 Air Force contract has been awarded to the National Research Corporation, Cambridge, Mass. for one year's study, construction and experimentation on photoemissive devices which convert the sun's energy to electric power. NRC's research division has been investigating a new conversion technique for spacecraft power supplies which promises substantial weight reductions over conventional silicon cell systems now in use.



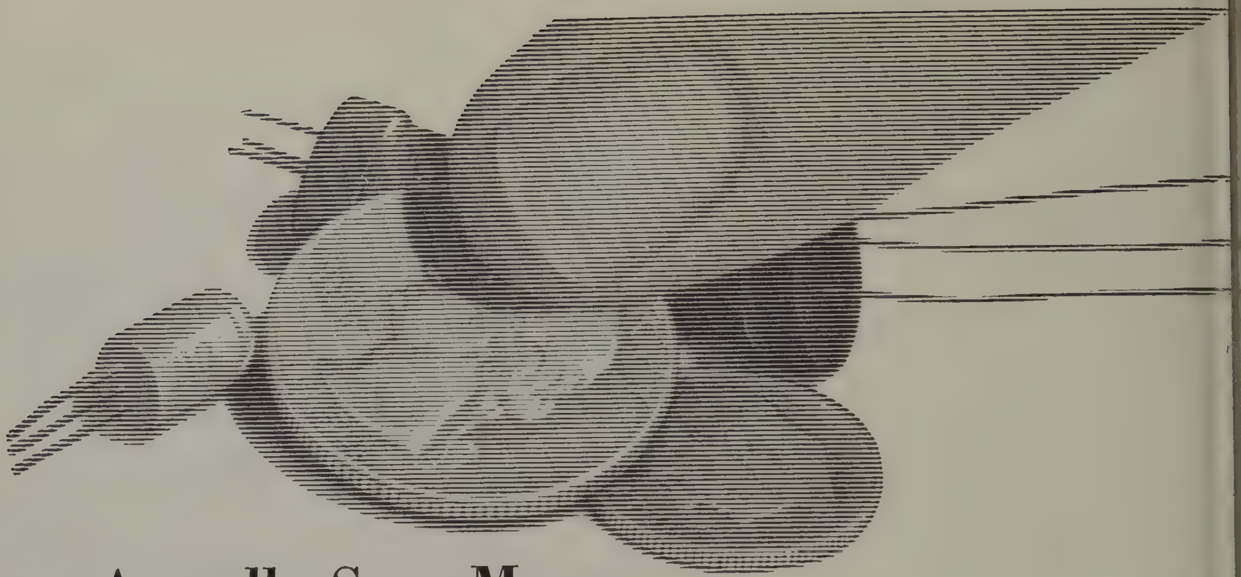
Editorial . . .

Optical and Infrared Masers

Since the invention of the maser in 1955 efforts have been made to extend its application from microwave to optical and infrared frequencies. Essentially the principle of operation consists of utilizing a suitable ensemble of molecular or atomic systems which possess radiation transitions between three nonequidistant levels, with relaxation time from the top to the intermediate level much shorter than that from the intermediate to the lowest level. Pumping the ensemble with random phase energy of the frequency corresponding to transitions from the lowest to the highest level, the consequent rapid decay provides an overpopulation of the intermediate state, from which the stimulated emission occurs. In order to facilitate the latter, the ensemble is placed in a cavity having one resonant mode near the frequency of desired transition. In this case the minimum necessary excitation for stimulated emission is inversely proportional to the Q of the cavity and is proportional to the half-width of the atomic resonance.

In the case of microwaves suitable levels are obtained by the use of Zeeman or Stark effects, but in the case of optical or infrared waves it is necessary to find suitable natural levels. Furthermore, the design of the cavity becomes much more difficult because of the larger number of modes and because of the greater losses encountered. The best solution found consists of the use of two flat parallel mirrors between which only the radiation with normal incidence remains, and any other is quickly deviated to the side walls and lost. If the maser material is in solid state, the latter may be utilized directly in the form of a slender rod with parallel silvered bases; if the maser material is gaseous, it may be placed in a transparent container (sapphire) between two external mirrors.

Recently successful experimental investigations have been conducted with solid state masers. Using a synthetic ruby crystal (aluminum oxide with 0.05% chromium oxide) cut as a cylindrical rod parallel or orthogonal to the c axis (0.5 cm diameter, 4 cm length) and illuminating this with incoherent green light, a red radiation of 6943 angstroms is stimulated, the bandwidth of which is less than one angstrom. The red coherent light is emitted within a cone angle of about 0.1 degree, where the deviation from the axis is a function of the imperfections of the crystal. One proposed gaseous cell consists of a potassium vapor ensemble at low pressure; in this case the transition between the 4s and the 5d levels would be induced by pumping at 0.405 microns, and a stimulated emission from the 5p to the 3d level would take place at 3.14 microns. It is hoped that the pumped power might be obtained from another potassium lamp, under proper excitation. So far, however, experiments in these areas have not been successful.



Thermal Evaluation of Microminiaturized Electronic Equipment

STEVEN MORRISON*

The trend in modern electronics is to diminish the size of equipment. The smaller the equipment the more severe the problem of transfer of heat becomes. Ultimately there is a thermal barrier which limits the process of miniaturization. This barrier is a function of the upper temperature limit of the component parts, the number of components in the equipment, and the external thermal resistance.

IN ORDER TO OPERATE electronic equipment, electric energy must be expended. Most of this electric energy expended in the operation of electronic equipment is converted into heat, while the remainder leaves the equipment in the form of electromagnetic radiation. The energy that goes into heat raises the internal temperature of the equipment.

Microminiaturized electronic equipment is temperature sensitive. In order to operate successfully, the temperature of the equipment must be held below a maximum value determined primarily by the minority charge carrier generation of the most temperature sensitive semiconductor material. Therefore, the amount of electrical power that microminiature electronic equipment can handle is limited by how much the electrical power that is converted into heat raises the temperature of the semiconductor to the maximum allowable value.

Energy will flow to its lowest level. In the presence of a voltage gradient, electric charge will flow away from the higher electrical potential energy. Correspondingly, in the presence of a temperature gradient, heat will flow away from the higher thermal potential energy. The electrical resistance may be defined as the voltage difference generated per unit charge flow. Similarly, the thermal resistance may be defined as the temperature difference generated per unit heat flow. Therefore, it is possible to draw a circuit with heat flow simulated by electric charge flow, temperature by voltage, and the thermal resistance by electrical resistance. Such a circuit for microminiaturized electronic equipment is drawn in *Fig. 1*. The analogous heat generators ($I_{1,\ 2,\ ---,\ n}$) raise the temperatures of the components ($E_{1,\ 2,\ ---,\ n}$). The heat then flows through its own respective internal thermal resistance ($R_{1,\ 2,\ ---,\ n}$) from the component to the substrate at a cooler temperature (E_s). From there all the heat combines (I_e) to flow through the external thermal resistance from the substrate to the environment (R_e) to the still cooler environmental temperature (E_e), drawn as ground. For simplification, let the heat produced by each component and the internal thermal resistance of each component be equal.

$$I_1 = I_2 = --- = I_n \tag{1a}$$

$$R_1 = R_2 = --- = R_n \tag{1b}$$

Then the temperatures of all the components will be equal.

$$E_1 = E_2 = --- = E_n \tag{2}$$

Using Kirchoff's law, the heat flowing from the substrate to the environment is the sum of all the heat produced by the components.

$$I_e = I_1 + I_2 + --- + I_n = nI_1 \tag{3}$$

The temperature rise, E_{1s}, from a substrate to the component equals the heat produced by the component times its internal thermal resistance.

$$E_{1s} = I_1\,R_1 \tag{4}$$

The temperature rise, E_{se}, from the environment to the substrate equals the total heat produced by all components times the external thermal resistance

$$E_{se} = I_e\,R_e \tag{5}$$

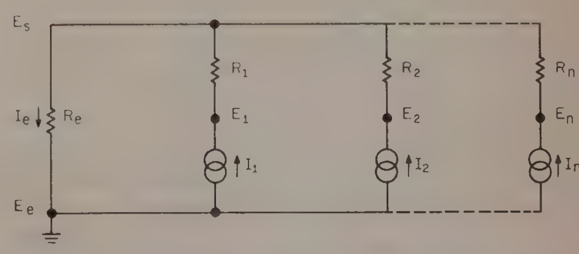


Fig. 1—Electrical circuit analogy of heat flow in microminiature equipment.

* This article was prepared while Mr. Morrison was associated with Cornell Aeronautical Laboratories, Inc., Buffalo, New York. Mr. Morrison is now with the Semiconductor Division of Westinghouse Electric Corp., Baltimore, Maryland.

Substituting Equation (3) into Equation (5)

$$E_{se} = nI_1 R_e \tag{6}$$

The total temperature rise, E_{1e}, from an environment to the component equals the sum of the temperature rises, substrate to component and environment to substrate.

$$E_{1e} = E_{1s} + E_{se} \tag{7}$$

Substituting Equations (4) and (6) into (7):

$$E_{1e} = I_1 (R_1 + nR_e) \tag{8}$$

When the number of components becomes very large E_{1e} is approximated by:

$$E_{1e} \approx I_1 n R_e \tag{9}$$

Rearranging Equation (9):

$$n I_1 = I_e = \frac{E_{1e}}{R_e} \tag{10a}$$

and,

$$I_1 = \frac{E_{1e}}{nR_e} \tag{10b}$$

From Equation (10a), the maximum power that can be dissipated within microminiaturized electronic equipment as a whole equals the maximum allowable temperature rise of the component divided by the *external* thermal resistance. From Equation (10b), the maximum power that can be dissipated within any one component equals the maximum allowable temperature rise divided by the external thermal resistance times the *number of components*. In order to increase the maximum power that microminiaturized equipment can dissipate, either materials must be used which allow a greater upper temperature limitation or equipment must be cooled more effectively by using forced air, liquid, or evaporative cooling where the cooling rate is substantially higher than natural convection and radiation cooling. In microminiaturized equipment, if the number of components is increased, the power through each component is proportionally decreased. The minimum power per component is determined either by the electronic performance desired or the component noise level, which ultimately limits the maximum number of components in microminiaturized equipment.

Acknowledgement

The guidance of James P. Welsh of Cornell Aeronautical Laboratory under whose supervision this study was performed and the helpful comments of Wayne Leipold and Dr. Robert Ziegler, are gratefully acknowledged.

Design of a High Accuracy Expanded Scale Meter Using Zener Diodes

P. D. KING*

A relatively low cost expanded scale device capable of high accuracy commensurate with economical considerations is described. There are expanded scale meters commercially available which have high advertised accuracy. These meters employ thermal bridges, differential meter movements, internal references, mechanical suppression, and various other means to obtain linear expanded scales and accuracy. Frequently, however, the cost of these devices is prohibitive.

Any Zener diode handbook, applications notes, semiconductor texts, etc., will generally contain a paragraph or page which briefly describes how Zener diodes can be used to obtain an expanded scale device with a minimum of cost. The circuit commonly shown is the basic type needed but requires refinements to overcome inaccuracies caused by the nonlinear characteristics of Zener diodes.

The basic circuitry, as shown in *Fig. 1*, has the inherent disadvantage of great inaccuracy at the low end of the expanded scale, i.e. at the Zener voltage of the device, caused by the change of dynamic resistance from a high value to a low value in the Zener breakdown region. This inaccuracy can be overcome by fitting the meter scale to the characteristics of the

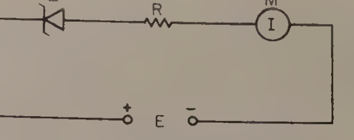


Fig. 1 — Basic circuit.

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individual device. The scale is then very non-linear, however, and should the diode require replacement the accuracy is generally lost. Therefore, this is not a very practical approach.

Design Considerations and Circuit Operation

The design outlined here is for an expanded scale of 12v to 16v *d-c*, total current at 16v of 1.0 *ma d-c*. *Fig. 2* shows the complete circuit described in the following paragraphs.

The main consideration in the design was the maintenance of meter accuracy and expanded scale linearity without the use of specialized components. To accomplish this a Zener diode was needed with a maximum ±1% tolerance in Zener voltage, an extremely sharp breakdown or "knee" in the reverse direction, and effectively zero dynamic impedance in the Zener or avalanche region, or in other words, an "ideal" diode. Since an ideal diode does not exist, the circuit was designed to simulate an ideal condition.

Z_1 and Z_2 are PS6314A Zener diodes with ±5% tolerance of the nominal Zener voltage (E_Z) of 10.5 volts measured at a test current (I_Z) of 200 μA. The maximum E_Z range of this Zener is then 10 to 11 volts which will insure a reading at the low end of the expanded scale.

Potentiometer R_1 is a null adjustment which sets the resistance of the parallel combination at a maximum and effectively averages the characteristics of the Zeners. R_1 is large enough so that the dynamic impedance of the Zener diodes is rendered negligible.

Diodes D_1 and D_2 are 1N913 low voltage regulators which, by virtue of their non-linear forward characteristics, tend to linearize the avalanche region of the Zener diodes and compress the high end of the expanded scale, making it linear with the low end of the scale.

It was desired that any mechanical suppression needed could be done by the zero adjustment on the meter itself. It was found necessary to add diode D_3, a 1N913, as a non-linear voltage dropping device to suppress the needed value of approximately 500 *mv*. The meter zero adjusting screw then became an efficient vernier adjustment for the required suppression.

Potentiometer R_3 is a scale adjustment for calibrating the device at the center scale value, in this case 14 volts. After nulling the meter with adjustment R_1, a potential of 12 volts is applied at the terminals and the meter zero screw adjusted for a 12 volt reading. A potential of 14 volts is then applied to the terminals and R_3 adjusted for a meter reading of 14 volts. It may be necessary to recheck the 12 volt reading and then the center scale reading a second time.

Figure 3 is a plot of the deviation from median readings for a sample of PS6314A diodes. The device can be calibrated to overcome the deviation of diode pairs for each pair thus leaving the accuracy of the meter itself as the limiting factor. The circuit without diodes D_1 and D_2 will have more than twice the deviation shown in *Fig. 3*. The meter used in the expanded scale device is a 0-1.0 *ma d-c*, ±2%, with 180 ohms internal resistance. The equipment used to obtain the data for *Fig. 3* were two ±1% multimeters,

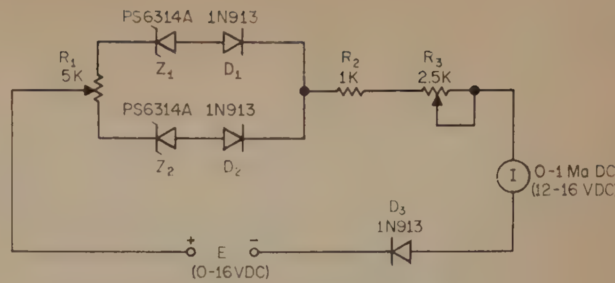

Fig. 2 — Complete circuit.

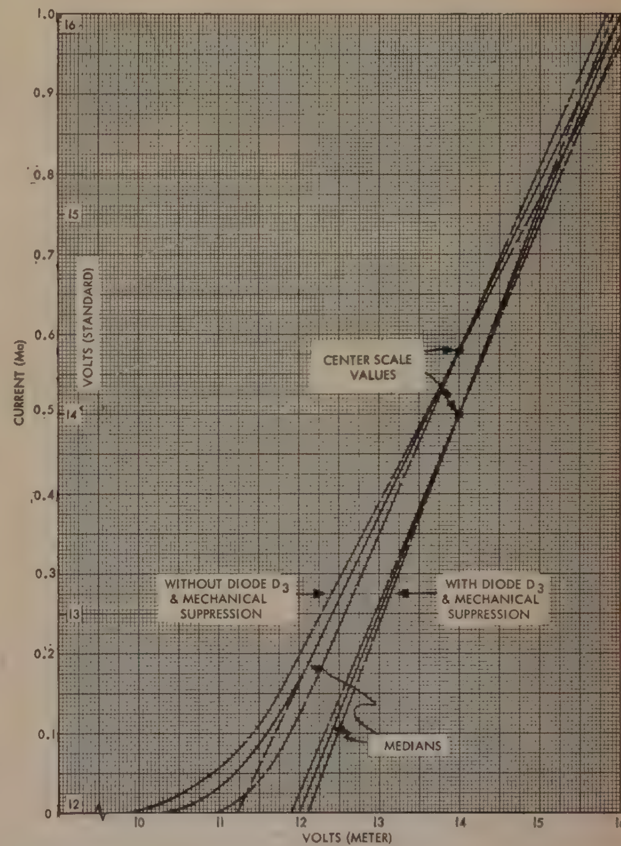

Fig. 3—Maximum deviation from the median.

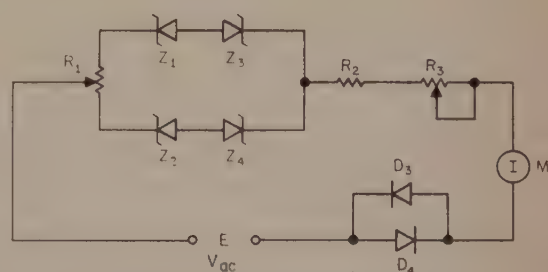

Fig. 4. — Circuit modified for A-C.

for voltage and current readings, and a 0-50 volt *d-c* power supply with 1% ripple.

Conclusion

As can be seen from *Fig. 3*, the maximum error that would be introduced by the circuit components at the high and low ends of the expanded scale is 1.25%. On a production basis it would be highly practical to select matched Zener diodes and very probable that this source of error can be eliminated.

The series diodes D_1 and D_2, because of their operation in the forward direction, provide some temperature compensation of the Zener diodes. D_1 and Z_1, D_2 and Z_2 can be matched to provide temperature coefficients as low as 0.05 $mv/°C$.

A slight modification to the circuit readily adapts it for use with an *a-c* rectifier type meter. *Fig. 4* shows replacement of diodes D_1 and D_2 with Zeners Z_3 and Z_4 of the same type as Z_1 and Z_2. D_4 has been added parallel to D_3 in the reverse direction to perform the same function as D_3 on the alternate half cycle.

Transistor Switching Analysis

DR. C. A. MEAD*

Part 3

Transistor Switching Performance

It was recognized early in the development of the junction transistor that the symmetry of the device implied the unique ability to *saturate*. Since both the collector and emitter junctions are capable of emitting minority carriers into the base region when forward biased, and since the diffusion current across the base is due to the difference in minority carrier density between the two junctions, it is clear that when the transistor is saturated *current may flow in either direction*, depending upon which density is the larger. In the saturated condition the transistor closely resembles a closed switch, and dynamic resistances of a few tenths of an ohm are easily obtained with small units. If, on the other hand, both junctions are reverse biased, the transistor is cut off and only the very small junction reverse currents flow. Hence the transistor resembles an open circuit, impedances of several megohms being common. When a transistor spends the majority of its time in one of two states, fully saturated or fully cut off, passing through the normally biased region only to get from one state to the other, it is said to be operating as a *switch*. A distinction should be drawn at this point between true switching service and non-saturating service. A so-called non-saturating switch is one where the transistor may become either cut off or normally biased (usually with a rather low collector voltage), but not saturated. Such operation is more properly termed Class *C* pulse amplifier service. When the transistor is not caused to saturate, its operation may be analyzed with adequate accuracy by the use of small signal equivalent circuits. However, when the transistor is caused to saturate, the analysis becomes quite complicated and has traditionally been avoided in circuit work. Here the lumped model comes into its own, since it transforms the difficult problem of transistor saturation and storage into one of simple *R-C* circuit analysis. The advantage of this approach for the circuit engineer is obvious.

Quasi Static Performance. Consider a transistor connected in the circuit shown in *Fig. 12*. For this analysis, we shall use the lumped model of *Fig. 9*. However, we may ignore C_1 and C_2 since we are only interested in slowly varying *d-c* quantities. The three regions of transistor operation will now be considered:

(a) Cut-Off. In the cut-off state, $\rho_1 = \rho_2 = -p_n$. Therefore

$$i_c = p_n G_2 = \frac{i_{co}(1+\beta)}{1+\beta+\beta_i}$$

which becomes

$$i_c \approx \frac{i_{co}}{1+\beta_i/\beta} \qquad \text{if} \quad \beta >> 1 \tag{7}$$

In the usual case, i_{co} is very small and hence the collector voltage is approximately equal to the supply voltage

$$v_c \approx V$$

The base current

$$i_b = -p_n(G_1+G_2) \approx -i_{co} \qquad \text{if} \quad \beta >> 1 \tag{8}$$

In this state the only significant contribution to the power dissipation of the transistor is from the collector.

$$P \approx i_c V = \frac{i_{co} V}{1+\beta_i/\beta} \tag{9}$$

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(b) Active Region. In the active region

$$\rho_2 = -p_n \approx 0 \quad \text{if} \quad i_c >> i_{co}$$

The collector excess density may be considered zero provided the collector current is large compared with i_{co}. Thus

$$i_c = \beta i_b$$
$$v_c = V - \beta i_b R$$

Since $\beta >> 1$ and the collector voltage is larger than the base voltage (since the transistor is not yet saturated), the power dissipated due to base current is negligible compared with that due to the collector current. Thus

$$P \approx \beta V i_b - \beta^2 R i_b^2 \qquad (10)$$

which reaches a maximum when $v_o \approx V/2$.

(c) Saturation. When the base current is increased to the point where $v_c = v_b$, the transistor saturates and the collector current becomes substantially independent of further increases in base current. Since both junctions are forward biased, the base and collector voltages will be neglected in comparison with V. Hence

$$i_c \approx V/R$$
$$i_b > V/\beta R$$

We may now solve for the excess densities ρ_1 and ρ_2 in order to obtain the junction voltages v_{be} and v_{bc}. We may write the equations for base and collector current as

$$i_c = (\rho_1 - \rho_2)\, G_d - \rho_2 G_2$$
$$i_b = \rho_1 G_1 + \rho_2 G_2$$

which may be solved for ρ_1 and ρ_2 writing β for G_d/G_1 and β_i for G_d/G_2

$$\rho_1 G_d \approx \frac{(1+\beta_i)\, i_b + i_c}{1 + \dfrac{\beta_i}{\beta} + \dfrac{1}{\beta}} \qquad (11)$$

$$\rho_2 G_d \approx \frac{\beta_{ib} - i_c}{1 + \dfrac{\beta}{\beta_i} + \dfrac{1}{\beta_i}} \qquad (12)$$

The combination ρG_d is a convenient quantity with which to deal since it has the dimensions of a current. When $\beta i_b = i_c$, the transistor has just become saturated and

$$i_c = \rho_1 G_d = V/R$$

At higher base currents the collector current remains essentially constant, but $\rho_2 G_d$ increases. Hence $\rho_2 G_d$ is a significant measure of the amount by which the transistor has been driven into saturation. We may now determine the junction voltage since

$$\rho_1 G_d = p_n G_d\, (e^{q v_{be}/kT} - 1)$$
$$\rho_2 G_d = p_n G_d\, (e^{q v_{bc}/kT} - 1)$$

Therefore

$$v_{be} = \frac{kT}{q} \,\mathrm{Ln} \left(\frac{\rho_1 G_d}{p_n G_d} + 1 \right)$$

$$v_{bc} = \frac{kT}{q} \,\mathrm{Ln} \left(\frac{\rho_2 G_d}{p_n G_d} + 1 \right)$$

where $p_n G_d$ may be determined from equations 5 or 6. Although the i_{co} expression is not as accurate as a measurement of junction voltage and current, it is often convenient for germanium units.

$$v_{be} \approx \frac{kT}{q} \,\mathrm{Ln} \left[\frac{i_c + (1+\beta_i)\, i_b}{\beta_i i_{co}} + 1 \right] \qquad (13)$$

$$v_{bc} \approx \frac{kT}{q} \,\mathrm{Ln} \left[\frac{(1+\beta)\, i_b - i_c}{\beta i_{co}} + 1 \right] \qquad (14)$$

The collector saturation voltage is just the difference between the two junction voltages. In most cases the drive current is sufficiently large that ρ_1 and ρ_2 are both much greater than p_n. Thus from equations 13 and 14

$$v_c \approx \frac{kT}{q} \,\mathrm{Ln} \frac{\rho_1 G_d}{\rho_2 G_d}$$

which from equations 11 and 12 becomes

$$v_c = \frac{kT}{q} \,\mathrm{Ln} \left(\frac{1 + \dfrac{1 + i_c/i_b}{\beta_i}}{1 - i_c/\beta i_b} \right) \qquad (15)$$

In the inverted connection the normal and inverse quantities merely exchange places and the junction voltages become

$$v_{bc} = \frac{kT}{q} \,\mathrm{Ln} \left[\frac{i_e + (1+\beta)\, i_b}{\beta i_{co}} + 1 \right] \qquad (16)$$

$$v_{be} = \frac{kT}{q} \,\mathrm{Ln} \left[\frac{(1+\beta_i)\, i_b - i_e}{\beta_i i_{co}} + 1 \right] \qquad (17)$$

Also, the emitter saturation voltage becomes

$$v_e = \frac{kT}{q} \,\mathrm{Ln} \left(\frac{1 + \dfrac{1 + i_e/i_b}{\beta}}{1 - i_e/\beta_i i_b} \right) \qquad (18)$$

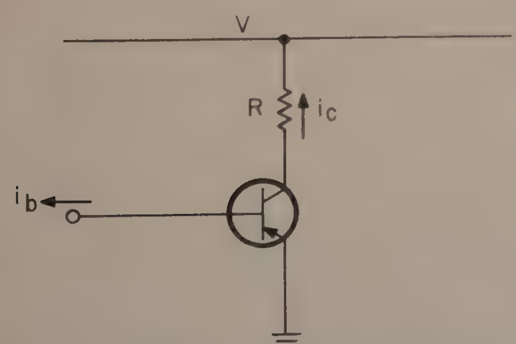

Fig. 12—Elementary transistor switch.

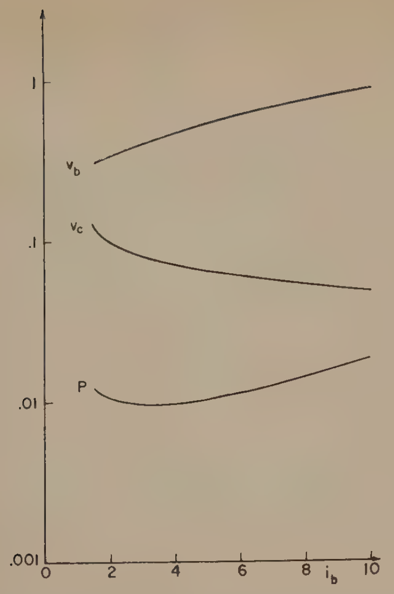

Fig. 13—Voltage and power variation for normally connected transistor.

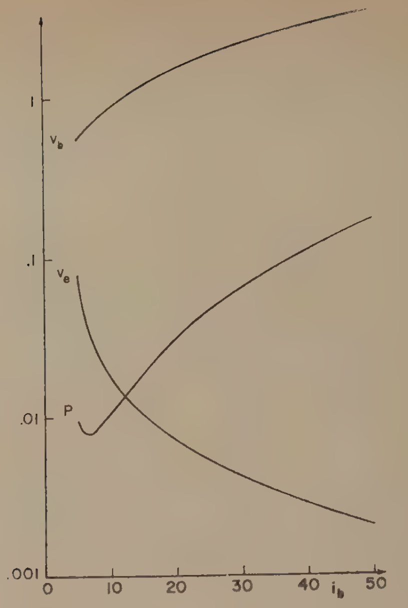

Fig. 14—Voltage and power variation for inversely connected transistor.

Plots of the base input voltage, saturation voltage, and power dissipation for a typical switching transistor operating in the normal and inverse connections are shown in *Figs. 13* and *14*. It is of interest to note the minimum in power dissipation which occurs at some base drive current. Clearly this drive current represents an optimum operating point for the particular transistor and collector current involved. The serious nature of large overdrive currents is quite apparent.

Dynamic Resistance. The resistance of a saturated transistor to small *a-c* signals is often of interest. This dynamic resistance is given by

$$R_s = \frac{\delta v_c}{\delta i_c}$$

for the normal connection and may be obtained from equation 15.

$$R_s = \frac{kT}{q}\left[\frac{1}{(1+\beta)\, i_b - i_c} + \frac{1}{(1+\beta_i)\, i_b + i_c}\right] \tag{19}$$

A similar expression is obtained for the inverted connection, only the roles of the collector and emitter are interchanged and β is interchanged with β_i. For sufficiently large drive currents

$$R_s \approx \frac{kT}{q}\left[\frac{\beta+\beta_i}{\beta(1+\beta_i)\, i_b}\right] \quad \beta >> 1 \tag{20}$$

which shows the saturation resistance inversely dependent on β, β_i and the drive current. The importance of *both* β and β_i *is* dramatically illustrated by this formula.

All transistors have certain ohmic resistances associated with their collector and base circuits due to the semiconductor material between the active region of the device and its contact to the outside world. For the first approximation we may assume these resistances constant, and if the voltage drops across them are not negligible, we must add them to the appropriate voltages already calculated. For switching transistors made by the alloying process, and many others, the collector series resistance is negligible, but the base resistance R_b should always be taken into account. The total base voltage thus becomes

$$v_b = v_{be} + i_b\, R_b$$

Since we are considering base currents up to very high values, we may no longer neglect the power dissipation in the base circuit.

$$P = v_c i_c + v_{be} i_b + i_b^2\, R_b \tag{21}$$

As we have noted, a number of simplifying assumptions have been made which under many conditions may be very questionable. However, for practical circuit design one often uses models which are greatly oversimplified, not because of their extreme accuracy but because they provide approximate answers and still allow a qualitative understanding of the problem. For example, the use of small signal equivalent circuits without regard to the magnitude of the signal level is an accepted engineering procedure. The nonlinearities are taken into account qualitatively after the main circuit behavior has been determined from the linear analysis. The lumped model serves in the same capacity for switching problems as a small signal equivalent circuit does for problems where the transistor is normally biased. It provides a straightforward method of obtaining results with reasonable

accuracy in the majority of cases and hence may claim certain engineering importance. The physical insight gained by the lumped model analysis is often much more valuable than a slight improvement in accuracy, since it enables the analyst to make qualitative statements concerning changes in circuit parameters, a very important step in the design procedure.

Transient Response.[8] Again we shall consider a junction transistor connected as shown in *Fig. 12.*

(a) Turn On. In the cut-off condition $i_b = -i_{co}$ as before. Now let us apply a positive current step of magnitude I_1 (large compared to i_{co}) and calculate the collector current response. As long as the transistor remains normally biased, the collector current may be computed from small signal formulae

$$i_c(s) = \frac{\beta i_b(s)}{1 + \frac{s}{\omega_\beta}} = \frac{\beta \omega_\beta I_1}{s(s + \omega_\beta)}$$

$$i_c = \beta I_1 (1 - e^{-\omega_\beta t})$$

However, the collector remains reverse biased only so long as

$$i_c < V/R$$

Thus the collector current rises toward the asymptote βI_1 with time constant $1/\omega\beta$. If $\beta I_1 > V/R$, the transistor will saturate when the collector current reaches V/R. The "rise time" required is thus

$$t_r = -\frac{1}{\omega_\beta} \ln \left(1 - \frac{V}{\beta I_1 R}\right) \tag{22}$$

Usually the transistor is driven quite hard in order to minimize the rise time. Under these conditions $\beta I_1 >> V/R$ and we may expand the log, retaining only the first term

$$t_r \approx \frac{V}{\beta \omega_\beta R I_1}$$

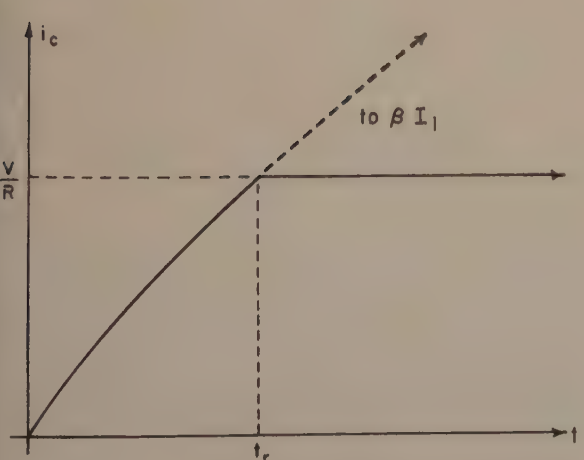

Fig. 15—Rise transient as predicted by transistor lumped model.

Since normally $\beta >> 1$, $\omega_\alpha \approx \beta\omega_\beta$. The rise time may be written

$$t_r \approx \frac{V}{\omega_\alpha R I_1} \tag{23}$$

It is thus clear that the alpha cut-off frequency is the determining factor in turn-on time and not β or ω_β alone. The conditions during turn-on are illustrated in *Fig. 15.*

(b) Storage. After the transistor has reached the steady state with $i_b = I_2$, let us suddenly reverse the base current to $i_b = -I_3$. As in the case of the diode, the collector junction remains forward biased since ρ_2 cannot change instantaneously. Hence the collector current remains $I_c = V/R$. After a "storage time" t_s, ρ_2 has reached zero and the transistor becomes normally biased.[10] In order to determine ρ_1 and ρ_2 during the storage period, we may determine their initial values from the steady state conditions given by equation 12, assuming $\beta >> 1$

$$\rho_2(0) = \frac{\beta I_2 - I_c}{\frac{\beta}{\beta_i} + 1} \qquad I_c = V/R \tag{24}$$

The transient densities may be found by superposing the steady state solution above (for $I_c = V/R$, $i_b = I_2$) upon the solution for a negative base current step of magnitude $I_2 + I_3$ and constant collector current $i_c = 0$.

The result of this calculation, assuming $\beta >> 1$ is

$$\rho_2 G_d \approx (I_2 + I_3) \frac{\beta\beta_i}{\beta + \beta_i} e^{-bt} - \frac{\beta_i I_c + \beta\beta_i I_3}{\beta + \beta_i} \tag{25}$$

where $I_c = V/R$ and

$$b \approx \frac{\omega_\alpha \omega_{\beta i} + \omega_\beta \omega_{\alpha i}}{\omega_\alpha + \omega_{\alpha i}}$$

The "storage time" t_s ends when ρ_2 reaches zero. Hence

$$e^{-bt_s} = \frac{\beta_i I_c + \beta\beta_i I_3}{\beta\beta_i (I_2 + I_3}$$

or

$$t_s = \frac{1}{b} \ln \frac{I_2 + I_3}{I_3 + \frac{I_c}{\beta}} \tag{26}$$

from which it is clear that the storage time may be reduced by using large turn-off currents. I_2 must be greater than I_c/β for the transistor to be saturated, but the overdrive may be reduced to decrease the storage time. *The controlling time constant for the storage period is* b, hence for small storage times *both* ω_β and $\omega_{\beta i}$ should be large.

If these frequencies are nearly equal

$$b \approx \omega_\beta \approx \omega_{\beta i}$$

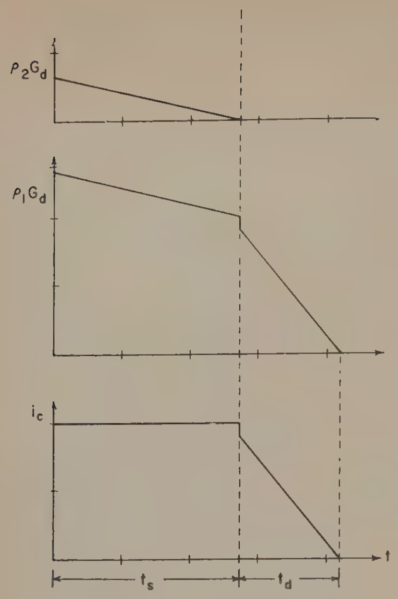

Fig. 16—Storage and decay transients as predicted by transistor lumped model.

Plots of ρ_1, ρ_2 and i_c during the storage period are shown in *Fig. 16*.

(c) Turn Off. When ρ_2 approaches zero, the collector current is made up of two components:

$$I_c = \rho_1 G_d + C_2 \frac{d\rho_2}{dt}$$

However, as the collector junction becomes reverse biased, $d\rho_2/dt$ abruptly becomes zero since ρ_2 cannot become less than $-p_n$ and the lumped model predicts a slight discontinuity in collector current. In reality the actual current changes smoothly, and this is another case where the lumped nature of the model fails to give the completely correct physical picture. However, for purposes of calculating the "decay time" or time required for i_c to reach zero, the lumped model expressions including the discontinuity will be more accurate than the corresponding expressions assuming no discontinuity. The reason is that the true collector current very quickly approaches the predicted value as an asymptote and by the time i_c approaches zero, the lumped model expression is quite accurate. Let us therefore calculate the magnitude of the discontinuity.

$$\Delta i = C_2 \left.\frac{d\rho_2}{dt}\right|_{t = t_s} = -\frac{C_2}{G_d}\, b\, \frac{(\beta_i I_c + \beta\beta_i I_3)}{\beta + \beta_i}$$

Substituting for b and assuming $\beta >> 1$

$$\Delta i = -(I_c + \beta I_3)\left(\frac{\omega_\beta}{\omega_\alpha + \omega_{\alpha i}}\right)$$

Thus under normal circumstances the relative magnitude of the discontinuity is quite small. However for very large overdrive currents it may become important. Under these conditions

$$\Delta i \approx -\beta I_3 \frac{\omega_\beta}{\omega_\alpha + \omega_{\alpha i}} \qquad (27)$$

After ρ_2 reaches zero, the transistor is again normally biased and we may use the small signal approach, as with the turn-on period. The collector current approaches the asymptote $-\beta I_3$ with a time constant $1/\omega_\beta$. During this period $i_c = \rho_1 G_d$

$$i_c = (I_c - \Delta i)\, e^{-\omega_\beta t} - \beta I_3 \,(1 - e^{-\omega_\beta t})$$

The "decay time" t_d is the time required for i_c to reach zero

$$t_d = \frac{1}{\omega_\beta} \ln\left(1 + \frac{I_c + \Delta i}{\beta I_3}\right)$$

For large turn-off current $I_3 >> I_c/\beta$ and we may approximate the logarithm. The decay time therefore becomes

$$t_d \approx \frac{1}{\omega_\alpha}\left(\frac{I_c}{I_3} - 1 + \frac{1}{\omega_{\alpha i}/\omega_\alpha}\right) \quad \text{if} \quad \beta >> 1 \qquad (28)$$

Thus, as with the rise time, *the decay time is determined by the magnitude of the drive current and the α cut-off frequency*, and not by β or ω_β alone.

After the turn-off period, the transistor is cut off and the collector current resumes its small steady-state value as given by equation 7. Comparing the expression for rise time as given in equation 23, we see that the decay time is always less than the rise time for a given base drive current. This is true because recombination is *helpful* during the decay period but *harmful* during the rise period. ■ ■

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Flow Graph Analysis—Further Advantages

G. H. BURCHILL*

EXPERIENCE WITH FLOW GRAPH TECHNIQUE shows that it has very useful features beyond those which have been already described. The method itself (due largely to S. J. Mason) and its practical application were explained by T. P. Sylvan, "Flow Graph Analysis of Transistor Circuits," in *Semiconductor Products*, January/February 1958. It is assumed that the reader is familiar with the method, and this article is confined to the features referred to above. It has been pointed out that the technique is something of an art, which requires practice, and that there are therefore many possible graphs for any one problem.

The circuit of a very simple transistor amplifier is shown in *Fig. 1*, along with its equivalent circuit. A flow graph is shown in *Fig. 2*. The transistor is connected common-emitter, and h parameters are used. The flow graph represents the following equations, v_i independent:

$$i_i = v_i/h_{ie} - v_o\, h_{re}/h_{ie} \tag{1}$$

$$i_L = i_i\, h_{fe} + v_o\, h_{oe} \tag{2}$$

$$v_o = -i_L\, R_L \tag{3}$$

Voltage amplification:

$$\frac{v_o}{v_i} = -\frac{\dfrac{h_{fe}}{h_{ie}} R_L}{1 + h_{oe} R_L - h_{re} \dfrac{h_{fe}}{h_{ie}} R_L} \tag{4}$$

Input admittance:

$$\frac{i_i}{v_i} = \frac{\dfrac{1}{h_{ie}} (1 + h_{oe} R_L)}{1 + h_{oe} R_L - h_{re} \dfrac{h_{fe}}{h_{ie}} R_L} \tag{5}$$

Output admittance:

$$\frac{i_o}{v_o} = h_{oe} - h_{re} \frac{h_{fe}}{h_{ie}} + \frac{1}{R_L} \tag{6}$$

Equations (4), (5), and (6) giving respectively the voltage amplification, input admittance and output admittance, are written by inspection of the graph. Equations (4) and (5) follow directly from the method previously described. Equation (6) is written by mentally disconnecting the load resistor to make v_o independent, and setting v_i equal to zero. The term $1/R_L$ is then added to the resulting expression, the load resistor being considered as part of the amplifier. Equation (6) also assumes that the generator impedance is zero; if necessary the value of generator impedance can be included in series with h_{ie}.

A useful feature about Equations (4), (5) and (6) is that each term gives quantitative information about a certain definite effect in the circuit. This is in contrast to the usual algebraic expression which is apt to combine these effects in a relatively complicated manner. Numerical substitution in the latter type of expression is likely to lead to a succession of numbers which convey little information in themselves until the final answer is reached.

To make this clearer, consider numerical substitution in Equation (4). Assume that the transistor parameters are:

$$h_{ie} = 1500$$
$$h_{fe} = 50$$
$$h_{re} = 11 \times 10^{-4}$$
$$h_{oe} = 50 \times 10^{-6}$$

If the value of R_L is taken as 6800 ohms, we then have:

$$\begin{aligned} -h_{fe}\, R_L/h_{ie} &= -50 \times 6800 / 1500 = -227 \\ +h_{oe}\, R_L &= 50 \times 10^{-6} \times 6800 = +0.34 \\ -h_{re}\, (h_{fe}\, R_L/h_{ie}) &= 11 \times 10^{-4} \times 227 = -0.25 \\ & \qquad\qquad\qquad\qquad\quad \overline{0.09} \\ \text{The determinant} &= 1.09 \end{aligned}$$

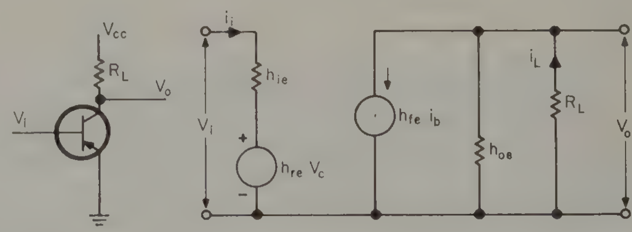

Fig. 1—Simple transistor amplifier and its equivalent circuit.

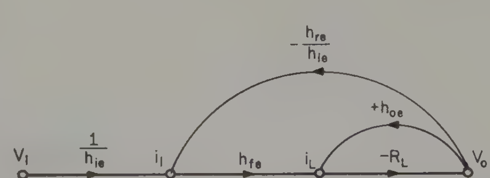

Fig. 2—Flow graph for simple transistor amplifier.

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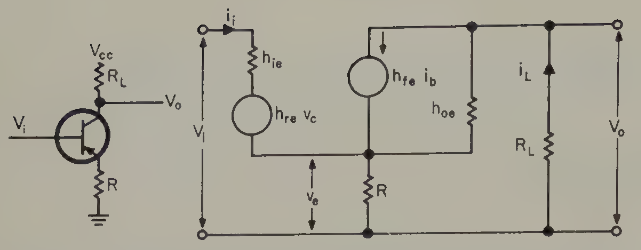

Fig. 3—Transistor amplifier with unbypassed emitter resistor, and its equivalent circuit.

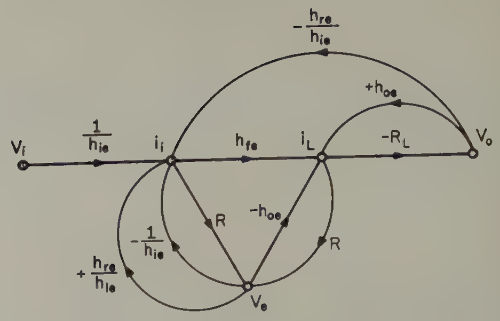

Fig. 4—Flow graph for Fig. 3.

Voltage Amplification:

$$v_o/v_i = -\ 227/1.09 = -\ 208$$

The expression $h_{fe}\ R_L/h_{ie}$ gives the approximate voltage amplification, as is well known.

The term $h_{oe}\ R_L$ is a "feedback factor" due to the fact that not all of the current produced by the current generator arrives at the load resistor.

The term $h_{re}\ h_{fe}\ R_L/h_{ie}$ is the feedback factor due to the presence of h_{re} and the internal feedback through the transistor.

As a more complex example, suppose that a 47 ohm unbypassed emitter resistor is added to the amplifier. The circuit and its equivalent are shown in *Fig. 3.* The flow graph is shown in *Fig. 4.* In comparison with *Fig. 2, Fig. 4* contains a new node, v_e, and new branches in accordance with the following equations:

$$v_e = i_i\ R + i_L\ R \tag{7}$$

$$i_i = v_i/h_{ie} - v_o\ h_{re}/h_{ie} + v_e\ h_{re}/h_{ie} - v_e/h_{ie} \tag{8}$$

$$i_L = i_i\ h_{fe} + v_o\ h_{oe} - v_e\ h_{oe} \tag{9}$$

The significant new terms are:

$R/h_{ie} = 47\ /\ 1500$	$= 0.03$
$h_{fe}\ (R/h_{ie}) = 50 \times 0.0313$	$= 1.57$
the former determinant	$= 1.09$
the new determinant	$= 2.69$

The voltage amplification is given by:

$$v_o/v_i = -\ 227/2.69 = -\ 84$$

The term R/h_{ie} is due to the presence of the emitter resistor in the input circuit. It would be the most important new term if the resistor had been inserted in series in the base lead.

The principal feedback factor is $h_{fe}\ R/h_{ie}$, due to the feedback intentionally introduced through the emitter resistor, and is indicative of the reduction in distortion and improvement in stability to be expected.

While no general principles for drawing flow graphs have been given, it is evident that these ex-

Voltage amplification:

$$\frac{v_o}{v_i} = -\frac{\frac{h_{fe}}{h_{ie}} R_L - \frac{h_{oe}}{h_{ie}} R\ R_L}{1 + h_{oe} R_L - h_{re}\frac{h_{fe}}{h_{ie}} R_L + \frac{R}{h_{ie}} + \frac{h_{fe}}{h_{ie}} R + h_{oe} R - h_{re}\frac{h_{fe}}{h_{ie}} R - \frac{h_{re}}{h_{ie}} R + \frac{h_{oe}}{h_{ie}} R\ R_L - h_{re}\frac{h_{oe}}{h_{ie}} R\ R_L} \tag{10}$$

Equation (10) follows directly from the flow graph. The original forward path and feedback loops are unchanged, but a new forward path and seven more feedback terms have been added. Examination of the new forward path shows that it represents transmission through the resistance components of the circuit, independent of transistor action, and calculation of the path gain shows that its effect is negligible. Five of the new feedback terms prove to have values of 0.01 or less, and will be neglected.

amples retain terms in their simplest forms, with a minimum of algebraic combination or other manipulation. Several trials may be needed when a new problem is attempted.

It has previously been shown that the method can greatly reduce the labor of circuit design. This article attempts to show that the numerical work can be arranged in the form of simple steps each conveying quantitative information about the circuit to the circuit designer.

Applications Engineering Digests

APPLICATIONS ENGINEERING DIGEST NO. 53

Circle 199 on Reader Service Card

Survey of Inverter Circuits Using Controlled Rectifiers; General Electric Co., Syracuse, N. Y. (H. R. Lowry and D. V. Jones)

One of the major applications for Silicon Controlled Rectifiers is converting *d-c* to *a-c*. The following material is a survey of various types of inverter circuits including both well-known circuits and recently developed circuits.

Parallel Inverter

The classical parallel inverter for Controlled Rectifiers (thyratrons, ignitrons, *SCR's*, etc.) is shown in *Fig. 53.1.*

When one *SCR* is conducting the capacitor *C* will be charged up to roughly twice the supply voltage so that when the second *SCR* is triggered into conduction the anode voltage of the first *SCR* will drop below ground, thus turning it off. The choke *L* must be large enough to act essentially as a constant current source.

The capacitor *C* must be large enough to compensate for the reactive *kva* of the load and also maintain a back bias on an *SCR* long enough for the *SCR* to recover its blocking characteristics. The chief difficulties with the inverter of *Fig. 53.1* occur during light load conditions when voltages on the *SCR* become quite large or else with low power factors loads when commutation may not take place and both *SCR's* conduct simultaneously.

An improved parallel inverter that was developed by W. McMurray and B. D. Bedford of the General Electric General Engineering Laboratory, is shown in *Fig. 53.2.*

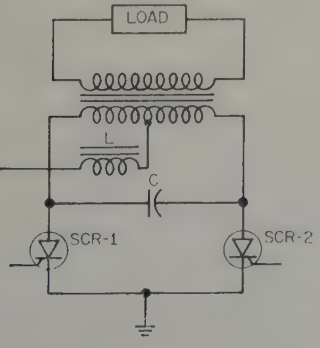

Fig. 53.1—Parallel Inverter.

In the McMurray-Bedford circuit, *C* and *L* are much smaller and chosen to give an oscillatory pulse across *L* when the second *SCR* is fired. The diodes compensate for leading or lagging power factor loads by feeding reactive power back into the supply. This circuit has substantially a square wave output voltage under all load conditions and does not create high voltages across the *SCR's* under lightly loaded or no-load conditions. When operating with reactive loads, it is necessary to apply gate signals until the reactive current flow through the feedback diode has stopped, so that the *SCR* can be refired and thus conduct for the remainder of the half cycle.

Series Inverters

A more satisfactory series inverter would result if the choke and capacitor only have to store enough energy to turn-off the *SCR* and not carry the full load power. This can be accomplished by the inverter of *Fig. 53.3.* In this circuit turning on *SCR* 1 allows the voltage on capacitor *C* to rise to almost twice the supply voltage by the resonant charging action of the choke and diode. Current will continue to flow into the load until *SCR* 2 is fired at which time the cathode of *SCR* 1 is driven positive shutting it off and then the charge on *C* dissipates itself in the load. *SCR* 2, the choke and capacitor can be quite small since they only have to carry the turn-off energy. The voltage across the load is a square wave of any duration since the pulse length is determined by the timing of the gate pulses and not the series resonant frequency of the choke and capacitor.

One disadvantage of this circuit is that the charge developed on the capacitor is independent of load and a capacitor must be used that is large enough to commutate the largest possible load. Another problem is that the choke, although small, must carry a *d-c* component and hence must include an air gap in its magnetic path.

By using a tapped choke, as in *Fig. 53.4*, both the above problems can be alleviated. The capacitor inrush current now flows in an opposite direction to the load current providing a flux resetting action. The voltage to which the capacitor charges increases with increasing load current making it possible to commutate heavy loads by charging the capacitor to several times the supply voltage. Since low capacity high voltage capacitors are generally smaller than high capacity, lower voltage units, a space saving may result from this circuit. ■■

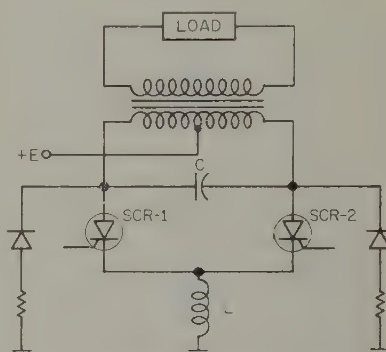

Fig. 53.2—McMurray-Bedford parallel inverter.

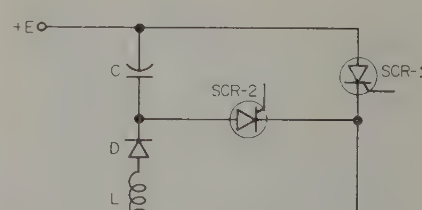

Fig. 53.3—Improved series inverter.

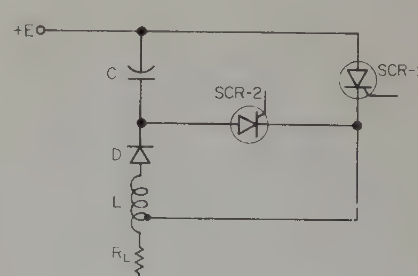

Fig. 53.4—Load sensitive series inverter.

APPLICATIONS ENGINEERING DIGEST NO. 54

(Circle 200 on Reader Service Card)

Silicon Transistor Voltage Regulator Overload Protection; Texas Instruments Incorporated, Dallas, Texas.

This application note suggests methods and circuits to protect regulator transistors against overloads caused by transients and load malfunctions. Although all possible means for overload protection will not be covered herein, the three basic techniques to be discussed are:

1. Protection by current limiting,
2. Protection by current interruption, and
3. Protection by load switching.

This note is concerned primarily with the protection of the control element in a series regulator. Being directly in the current path of the load, this element requires protection because it can become permanently damaged in a fraction of a second if the regulator output becomes short-circuited.

Protection by Current Limiting

Current-limiting overload protection is usually practical only with low-voltage, low-current regulators. This type of protection offers some advantage in that it is nearly instantaneous and the regulator will return to normal operation as soon as the overload condition is removed. Current-limiting protection can also be provided without causing transients in the circuit that might be noticed with other protection schemes.

Such a protective circuit, consisting of *R1, R2, D1,* and *Q1* is shown in *Fig. 54.1.*

During normal regulation operation, the voltage across *R1* is such that *D1* does not conduct, and the limiting transistor, *Q1,* operates in saturation because of the heavy forward bias. When *Q1* is operating in saturation, it appears as a low impedance to the series control element, *Q2.* When a predetermined load current is reached, *D1* begins to conduct in the reverse direction because of the added voltage drop across *R1.* A further increase of load current and voltage drop across *R1* reduces the base-emitter voltage, V_{BE}, on *Q1.* As V_{BE} decreases, the collector current of *Q1* tends to decrease and the collector voltage, V_{CB}, increases. The result is that, as the load current tends to increase above the maximum allowable value, *Q1* appears as a higher impedance to *Q2.* If the load becomes short-circuited, most of the unregulated input voltage appears as a voltage drop across *Q1,* and the current flow is equal to the maximum current determined by the adjustment of *R1.*

A disadvantage of this type of overload protection is that *Q1* must be capable of withstanding simultaneously the maximum load current and a voltage nearly equal to the unregulated input while a short-circuit load condition exists. For this reason, the circuit is usually limited to low-voltage and low-current regulators. However, current-limiting protection will find much more use in high-voltage and high-current regulators as transistors become available with higher voltage and current capabilities. Until that time, the protective circuits can be cascaded if the unregulated supply voltage is greater than the voltage rating of a single transistor.

Protection by Current Interruption

Current interruption is usually the most dependable protection if the overload can be detected and the load circuit interrupted before any damage is done to the regulator transistors. Fuses are sometimes used for regulator protection but they usually are not adequate when used alone. In many cases the clearing time of a fuse is longer than the time required to permanently damage the transistor that it is used to protect. To speed up the fuse action, the circuit shown in *Fig. 54.2* may be used.

The protection circuit in *Fig. 54.2* was designed for regulators of much higher current and voltage ratings than those shown previously. This circuit can detect an overload condition and cause the fuse to open in a very short time.

The controlled rectifier, *SCR1,* does not conduct during normal regulator operation and does not affect the regulator performance. *R4* is the only portion of the protective circuit that is normally in the regulator circuit, and it adds slightly to the regulator output resistance. A pre-determined overload current causes the voltage drop across *R4* to increase until it exceeds the breakdown voltage of *D1.* When *D1* breaks down, a gate current is supplied to *SCR1,* causing the controlled rectifier to conduct. It then conducts a high current while the regulator current remains comparatively low. The high current through *SCR1* will cause the fuse to open much faster than it would if protection were provided by the fuse alone.

The controlled rectifier must have a breakover voltage that is above the maximum voltage delivered by the rectifier and filter network. Otherwise, *SCR1* would conduct without an applied gate current.

Protection by Load Switching

Load switching can be used with high-voltage, high-current regulators that can not be adequately protected by current limiting or current interruption. Such a load switching circuit is shown in *Fig. 54.3.*

With the circuit connected to the regulator, load current begins to flow in the regulator as soon as *SCR1* is put into conduction by momentarily closing the normally open switch, *SW1. C1* then charges to the unregulated input voltage, and *SCR2* remains *off.* Regulator load current continues to flow until the voltage drop across *R2* exceeds the breakdown voltage of *D1.* When *D1* breaks down, *SCR2* will be supplied with a gate current and go into conduction. *C1* then discharges through *SCR2* and turns *SCR1 off.* No current will flow through the regulator when *SCR1* is *off.*

An overload at the regulator output causes the protective circuit to switch the load, including the regulator, out and switch *R1* into the circuit as the new load. The time required from a short-circuit output until *SCR1* is completely cut off is about 5 to 10 μsec. This time depends upon the size of *C1,* temperature, normal input and output voltages of the regulator, impedances in the circuit after *SCR2* turns on, and the short-circuit load current.

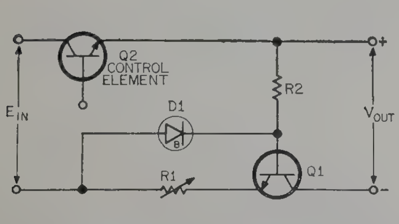

Fig. 54.1—Protective circuit using current limiting.

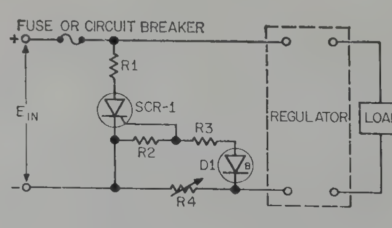

Fig. 54.2—Protective circuit using current interruption.

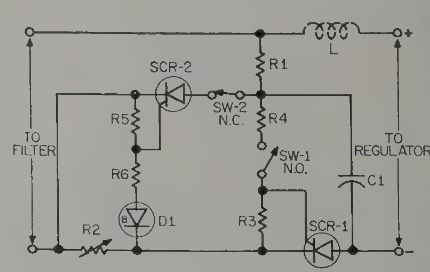

Fig. 54.3—Protective circuit using load switching.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from July 15, 1958 to Aug. 12, 1958. In subsequent issues, patents issued from Aug. 12, 1958 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

July 15, 1958

2,843,515 Semiconductor Devices—H. Statz, H. Schenkel. Assignee: Raytheon Company. A junction transistor having an α equal to or greater than unity, is provided by controlling the base region resistivity and width within limits which are related to the collector operating voltage.

2,843,516 Semiconductor Junction Rectifier —A. Herlet. Assignee: Siemens-Schuckertwerke Aktiengeselleschaft. A semiconductor rectifier having predetermined optimum rectifying properties within a range of temperatures controllable by the usual cooling devices.

2,843,541 Electrophoretic Deposition of Barium Titanate—S. Senderoff, W. E. Reid, Jr. Assignee: None. A method of coating a metal object with barium titanate by mixing finely ground barium tetanate with diethylene glycol, dymethyl ether, 1-nitropropane, or pyridine, and then coating said object with the barium titanate by electropharesis.

2,843,681 Transistor Amplifier—A. J. Van Overbeek. Assignee: North American Phillips Company, Incorporated. An amplifier circuit which provides reduced reaction between the output and input thereof.

2,843,743 Pulse Generator—D. J. Hamilton. Assignee: Hughes Aircraft Company. A transistorized pulse generator which provides short duration pulses having rapid rise and fall times, for driving a capacitive load without excessively loading the generator.

2,843,744 Transistor Oscillator Starting Circuit—J. H. Guyton. Assignee: General Motors, Incorporated. An oscillator having a single voltage source, and adopted to initiate oscillations when the output circuit is energized.

2,843,745 Tone Generator—D. H. Smith. Assignee: Bell Telephone Laboratories. A transistorized tone generator which uses the ripple component of a rectified current as the modulating frequency.

2,843,761 High Speed Transistor Flip-Flops —A. W. Carlson. Assignee: U.S.A. (Dept. of The Air Force). A transistor flip-flop which eliminates the hole-storage effect.

2,843,762 Bistable Transistor Trigger Circuit—R. L. Trent. Assignee: Bell Telephone Laboratories. A single transistor circuit which presents a high speed triggering characteristic and high stability with respect to temperature and component variations.

2,843,763 Apparatus For The Switching of Electric Power Circuits Without Contact —W. Kafka, G. Sichling, M. Tschermak. Assignee: Siemens Schuckertwerke Aktiengesellschaft (Germany). Apparatus of the character described above which utilizes magnetic barrier semiconductor devices as switching elements.

2,843,764 Semiconductor Stabilizing Circuit—R. H. Okada. Assignee: Burroughs Corporation. A transistor circuit which presents means for controlling the lower peak of the emitter voltage-current characteristic so that transistors having dissimilar operating characteristics will have similar low-peak values.

2,843,765 Circuit Element Having a Negative Resistance—P. R. Raoul. Assignee: International Standard Electric Corporation. An element having a semiconductor metal contact which may be utilized in negative resistance circuits, and which can be manufactured more easily than transistors.

2,843,766 Inpulse-Converting Circuit-Arrangement—G. Rosier, H. Volkers. Assignee: North American Phillips Company, Incorporated. A transistor circuit for converting a train of impulses of like sign into a train of positive and negative impulses.

2,843,809 Transistors—A. A. Varela. Assignee: Corvey Engineering Company. A transistor having an electrochemically fabricated body, which, in turn, has electrolytically etched surface barriers extending from an etch fractured edge, said transistor having an electroplated electrode in intimate contact with each of said barriers.

2,843,815 Transistor High Voltage Power Supply—G. E. Driver. Assignee: U.S.A. (A.E.C.) A low weight, small size, high efficiency transistorized high voltage power supply.

July 22, 1958

2,843,914 Method of Producing a Photo Conductive Device—F. Koury. Assignee: Sylvania Electric Products. A method of producing a cadmium-sulphide photoconductive device by causing small crystals of said substance to coalesce into large crystals thereof through the action of heat.

2,844,411 Process of Purifying Liquid Silicon Halide—R. A. Pellin. Assignee: E. I. DuPont De Nemours & Company. A purification process that involves treatment of the halide with sulphuric or phosphoric acid to remove impurities.

2,844,460 Method of Purifying Germanium —G. B. Finn, Jr., S. Mayburg. Assignee: Sylvania Electric Products, Incorporated. A process that includes heating germanium to between 500°C and 900°C in a vacuum not higher than 10^{-4} mm of mercury.

2,844,493 High Resistance Photoconductor —H. Schlosser. Assignee: Horizons, Incorporated. An As_2S_3 photoconducting element possessing high resistivity, transparency to visible light, sharp spectral response, and other marked advantageous properties.

2,844,531 Method of Producing Cavities In Semiconductor Surfaces—M. B. Prince. Assignee: Bell Telephone Laboratories. A method which produces said cavities by eletrolytic etching.

2,844,543 Transparent Photoconductive Composition—R. A. Fotland. Assignee: Horizons, Incorporated. A photoconductive element consulting of a transparent photoconductive material comprising As^2S^3 and about 2.5% to 10% of selenium.

2,844,640 Cadium Sulphide Barrier Layer Cell—D. C. Reynolds. Assignee: U.S.A. (Dept. of the Air Force). A Cadium sulphide cell designed for use as an instrument for converting solar energy into electrical energy.

2,844,667 Cascade Transistor Amplifiers— R. E. Yaeger. Assignee: Bell Telephone Laboratories. A device which provides a constant emitter current bias for a pair of amplifier stages having different circuit configurations.

2,844,770 Semiconductive Device and Method of Producing Same.—J. C. Van Vessen. Assignee: North American Philips Company, Incorporated. An electrode system using electrodes surrounded by a refractory material the purpose of which is to restrict the area over which the electrode material would flow when heated during the time said electrode was being secured to the body.

2,844,772 Semiconductive Device and Method For Making Same—F. Weil. Assignee: North American Philips Company, Incorporated. The process of manufacturing heat sensitive semiconductive device.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

2,844,737 Semiconductive Materials—E. E. Hahn, M. L. Schultz, G. A. Morton, A. G. Morris. Assignee: Radio Corporation of America. A device that can sense radiation in the 5 to 10 micron wave length range, which can detect radiation having a wavelength greater than 1.7 microns at temperatures as low as that of liquid nitrogen and which is constructed of a material having an excitation energy level gap of 0.1 to 0.2 eV at obtainable temperatures.

2,844,739 Sawtooth Current Wave Generator—Javins. Assignee: Radio Corporation of America. A transistorized circuit in which a feedback pulse obtained from an inductance coil terminates the retrace portion of the cycle after a fixed time interval.

2,844,769 Semiconductor Electrode Systems—J. Erkelens, J. Kamerman, W. A. Roovers. Assignee: North American Philips Company, Incorporated. A transistor mounting and electrode system which attempts to alleviate the problem of heat transfer to the crystal itself.

2,844,795 Transistor Reactance Device-F. G. Herring. Assignee: Hazeltine Research Incorporated. A device which can be used to control the operations of an electrical device operating at frequences above .1 megacycle.

July 29, 1958

2,845,370 Semiconductor Crystal Rectifier—P. R. Aigran. Assignee: International Standard Electric Corporation. A process for activating and controlling the conversion betmeen n-type and p-type material in order to reduce diffusion.

2,845,371. Process of Producing Junctions In Semiconductors—G. G. Smith. Assignee: Raytheon Company. A method of forming junction crystals using a cathode ray heating device to form longitudinal **n-p** junctions.

2,845,372 Grown Junction Type Transistors and Method of Making Same—M. E. Jones, W. A. Adcock. Assignee: Texas Instruments, Incorporated. A growing method utilizing a crystal pulling technique and a technique for alloying aluminum electrodes to the crystal.

2,845,373 Semiconductor Devices and Methods of Making Same—H. Nelson. Assignee: Radio Corporation of America. Methods of making rectifying barriers in silicon or silicon alloy semiconductor bodies.

2,845,374 Semiconductor Unit and Method of Making Same—M. E. Jones. Assignee: Texas Instruments, Incorporated. The production of graded junction devices by vacuum plating and heat treating techniques.

2,845,497. Transistorized Amplifier Circuits—F. E. Barron, S. F. Lybarger. Assignee: E. A. Meyers & Sons, Incorporated. A transistorized amplifier circuit which avoids blocking, and which has smooth volume control action with no unwanted input impedance change at low volume.

2,845,546 Amplitude Discriminator—J. A. Purcell, H. J. Beal. Assignee: International Business Machines. Apparatus employing a photo transistor and a light beam to measure the displacement of a vibrating object.

2,845,547 Variable Time Base Generator—C. F. Althouse. Assignee: U.S.A. (Dept. of the Navy). A transistorized blocking oscillator type time base generating circuit which produces constant-width, frequency-insensitive, linear sawtooth sweep voltage.

2,845,548 Static Time Delay Circuit—S. D. Silliman, J. F. Reuther. Assignee: Westinghouse Electric Corporation. A time delay circuit, using nonthermionic components for a signal having a step function waveform.

August 5, 1958

2,846,340 Semiconductor Devices and Method of Making Same—D. A. Jenny. Assignee: R.C.A. A transistor having an emitter with a higher bandgap than the base region, said base having a graded impurity concentration.

2,846,346 Semiconductor Device—W. E. Bradley. Assignee: Philco-Corp. Electrolytic methods of producing semiconducting bodies possessing sections therein of extreme thinness, said formed bodies thereby be capable of fabrication into photo-cells and transistors possessing excellent frequency response.

2,846,493 N-Type Thermoelectric Devices—N. E. Lindenblad. Assignee: R.C.A. A high melting point n-type gold-nickel thermoelectric element characterized by a high rate of change of e.m.f. with respect to temperature.

2,846,494 Thermoelectric Devices—N. E. Lindenblad. Assignee: R.C.A. A high melting point p-type iron-aluminum thermoelectric element having a high temperature rate-of-change of e.m.f.

2,846,526 Potential Monitoring Circuit—E. P. Moore, R. L. Trent. Assignee: Bell Telephone Labs. Apparatus which provides simultaneous monitoring of potential variation on a large number of circuits.

2,846,579 Electric Oscillator Circuit—E. Wolfendale. Assignee: North American Philips Co. Inc. A transistorized circuit capable of producing sinusoidal oscillations.

2,846,580 Oscillator Circuit Arrangement—L. H. Light. Assignee: North American Philips Co. Inc. A transistor pulse oscillator capable of being used as a d-c voltage transformer.

2,846,581 Transistor Pulse Generator Circuit—H. Volkers. Assignee; North American Philips Co., Inc. A pulse generating system providing means for overcoming initial starting difficulties inherent in pulse generating systems.

2,846,583 Voltage Controlled Multivibrator Oscillator—L. I. Goldfischer, A Di Benedetto. Assignee: General Precision Laboratory Inc. A linear variable frequency oscillator for a relatively high range of frequencies.

2,846,592 Temperature Compensated Semiconductor Devices—R. F. Rutz. Assignee: I.B.M. A temperature compensated device wherein the compensating element is an element of the device itself.

2,846,594 Ring Counter—A. J. Pankratz, L. M. Schmidt. Assignee: Librascope Inc. A transistorized ring counter.

2,846,625 Semiconductor Device—E. M. Gustafson, A. I. Schwartz. Assignee: Columbia Broadcasting System Inc. A liquid cooled, long-lived, sturdy semiconductor device having a low noise figure.

2,846,626 Junction Transistors and methods of forming them—H. P. Nowak. Assignee: Raytheon Manufacturing Company. A electrolytic process which may be used to fabricate several transistors from a block of material having one conductivity.

2,846,630 Transistorized Servo Positioner System, H. G. Boyle, R. W. Bradmiller, C. J. Parker, A. E. Plogstedt. Assignee: Avco Mfg. Corporation. A system which produces a reference voltage in decade steps and which is insensitive to short-term transient a-c noise.

2,846,652 Transistor Modulator—J. M. Clurven. Assignee: North American Phillips Co., Inc. A circuit arrangement which avoids losses and heavy current flow due to short circuits resulting from collector-base rectification.

August 12, 1958

2,847,329 Sensitization of Photoconductive Cells by the Use of Indium Vapor—L. E. Schilberg, G. G. Kretschmar. Assignee: U.S.A. (Navy Department). A process for the production of photoconductive elements by the evaporation in vacuum of cadmium telluride and indium onto a surface at temperatures between 580°C and 640°C.

2,847,335 Semiconductor Devices and Method of Manufacturing Them: R. Gremmelmaier, H. Welker. Assignee: Siemens Schuckertwerke Aktiengesellschaft. A method of production which involves fusing a semiconductive material onto a specially prepared electrode, said method being applicable to the fabrications of a number of devices having a wide range of properties.

2,847,336 Processing Semiconductor Devices—J. I. Pankove. Assignee: R.C.A. Means for producing p-n junction devices by introducing crystal imperfections at places in semiconducting bodies where it is desired to place a p-n junction electrode by an alloying or diffusion technique.

2,847,386 Electroluminescent Materials—R. M. Mazo, S. Larach. Assignee: R.C.A. Methods for producing electroluminescent materials by treating a mixture of zinc sulphide, zinc selenide and copper at high temperatures in an atmosphere containing free bromine.

2,847,509 Party Line Pay Station Identification—H. G. Evers, J. R. Wylie. Assignee: Leich Electric Co. A transistorized oscillator is used as a tone generator in an arrangement that allows regular subscribers and pay phones to be employed on the same party line.

2,847,519 Stabilized Transistor Signal Amplifier Circuit—A. I. Aronson. Assignee: R.C.A. In a transistorized system, a d-c feedback connection from the emitter of the output stage to the base of the driver stage effects stabilization of the operating point of the driver stage transistor of the power amplifier.

2,847,544 Silicon Semiconductor Devices—E. A. Taft, Jr., F. H. Horn. Assignee: General Electric Co., Inc. A noncrystalline silicon semiconductor device having pronounced photoconductive and thermosensitive characteristics and which is particularly photosensitive in the infrared region.

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Series Capacitors Applied to Power Rectifiers	App & Indust (AIEE) May 1960	Data are given concerning the effect of the series capacitor on the peak inverse voltages experienced by the rectifier elements.	L.J. Hibbard T.J. Bliss
Transient Decay of Current Through Paralleled Mercury Arc and Silicon Rectifiers	App & Indust (AIEE) May 1960	Distributed parameter technique in analyzing the decay of a large electrochemical potline *d-c* distribution under trip of a main *a-c* circuit breaker.	W.R. Hodgson
Semiconductor Strain Transducers	Bell Syst Tech J1 May 1960	Historical survey; brief phenomenological description; and various applications of semiconductor elements as strain transducers.	F.T. Geyling J.J. Frost
The Charge and Potential Distributions at the Zinc Oxide Electrode	Bell Syst Tech J1 May 1960	Capacitance measurements made on single crystal zinc oxide electrodes in contact with aqueous electrolytes are reported.	J.F. Dewald
Theory of Current Carrier Transport and Photoconductivity in Semiconductors with Trapping	Bell Syst Tech J1 May 1960	Fundamental differential equations are derived under the unrestricted approximation of electrical neutrality that admits trapping.	W. VanRoosbroeck
High Frequency Negative Resistance Circuit Principles for Esaki Diode Applications	Bell Syst Tech J1 May 1960	Conditions necessary for oscillation and amplification with single negative resistance diode, including stability criteria, gain and bandwidth.	M.E. Hines
A V.L.F. Thermal Relaxation Oscillator Using Temperature Dependent Resistors	Brit Comm & Elecncs May 1960	A thermistor having a negative resistance/temperature coefficient placed in series with a positive temperature coefficient resistor can be made to produce an oscillating current.	I. Aleksander
Transistorized Power Supplies for a Mass Spectrometer	Can J1 Physics May 1960	While a mass spectrometer itself may require a few hundred watts of regulated power, the regulating supplies often dissipate kilowatts.	R.D. Russell F. Kollar
Tubes or Transistors: A Realistic Assessment	Comm & Elecncs (AIEE) May 1960	Presentation of a few abstracts from available data, and listing of references for more complete information relative to the above.	R.E. Mou
The Versatile Transistor NOR Circuit	Control Eng May 1960	Discussion of the design and operation of a single module, the transistor NOR, that is capable of performing all of the logic functions in a control system	A.N. DeSautels
Operation of a Semiconductor Switch with a Different Type of Load	Elec Tech USSR May 1960	By generating specially shaped pulses it is possible to construct different transistorized control systems for electrical machines.	O.A. Kossov
Circuit Design with Rectifiers and Resistances	Elec Tech USSR May 1960	Theoretical discussion and analysis lead to typical equations which are utilized in the solution of examples given.	N.N. Kostabe
The Design of High Frequency Diffused Base Transistor Switches	Elecl Design News May 1960	Design considerations are presented, together with applications.	C.D. Simmons P.G. Thomas
Tunnel Diodes	Elecl Design News May 1960	A discussion of theory, parameters, and circuit applications.	Staff Members Texas Instruments Inc.
Introduction to Molecular Engineering	Elecl Mfg May 1960	The application of molecular science to the design of materials and devices, and their articulation into systems and definitions.	A.E. Javitz
Power Supply Circuit Design by Digital Computer Method	Elecl Mfg May 1960	Power supply circuity was designed with the aid of the IBM-704, and the laboratory data compared with computed data.	H.J. Joyal
Thermoelectric Heat Pumps	Elecl Mfg May 1960	Technical capability of commercially available thermoelectric devices; basic elements for custom-designed heat pumps and packaged component coolers for building into electronic equipment.	W.V. Huck J. Taylor T. Mulicia
A Stable Transistor AGC Amplifier	Elecnc Design May 1960	Transistor parameter variations and supply voltage fluctuations are internally compensated in the *agc* circuit described.	J. Shirman
Find Transistor Gain and Input Impedance Quickly Using Hybrid-Pi Equivalent	Elecnc Design May 1960	Three cases are illustrated, showing how to apply the hybrid pi to determine voltage gain and input impedance.	P. Margolin
A Physiological Stimulator Using Junction Transistors	Elecnc Engg (Br) May 1960	Output voltage variable from 0 to 25V; frequency variable from 2 to 100/sec; constant pulse-width of about 1 msec.	W.T. Catton L. Molyneux
Exhaustive Boolean Expressions	Elecnc Equip Engg May 1960	Technique provides eight standard forms capable of defining any Boolean function.	B. Hurley
Tunnel Diodes as Amplifiers and Switches	Elecnc Equip Engg May 1960	High operating speed, low noise capabilities, and resistance to nuclear radiation make tunnel diodes suitable for many applications in switching and amplifier systems.	T.P. Sylvan E. Gottlieb
Semiconductor Networks for Microelectronics	Electronics May 13, 1960	Description of how a circuit is developed from a diagram to a network on, and within, a single-crystal semiconductor wafer.	J.W. Lathrop R.E. Lez C.H. Phipps
Achieving Discriminator Levels with a Biased Input Diode	Electronics May 20, 1960	Triggering thresholds of this highly-accurate and stable pulse-height discriminator are set by adjusting bias of a diode.	F.S. Gaulding L.B. Robinson
Procedure for Designing Reciprocal Computer Circuits	Electronics May 20, 1960	Circuits with outputs inversely proportional to their inputs can be constructed using diodes, resistors and *d-c* voltage supplies.	A. Gill
Electronics in Japan	Electronics May 27, 1960	Report includes backgrounds; products and practices; research and engineering; marketing and export.	F. Leary
Negative-Resistance Amplifier Design	Electronics May 27, 1960	Design criteria are given; equations relating gain, gain-bandwidth, and stability, are presented.	J.B. Schultz H.B. Yin
Designing Solid State Static Power Relays	Electronics May 27, 1960	Discussion of design of silicon controlled rectifiers used in relays and circuit breakers having contact rating from milliwatts to kilowatts.	R.F. Blake

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The P-I-N Modulator, an Electrically Controlled Attenuator for MM and Sub-MM Waves	IRE Tr Micro T&T May 1960	Construction and performance of a millimeter wave modulator containing a *p-i-n* germanium structure inserted into a rectangular waveguide is described.	F.C. DeRonde H.J.G. Meyer O.W. Memelink
A Wide-Band UHF Traveling-Wave Variable Reactance Amplifier	IRE Tr Micro T&T May 1960	Techniques developed for designing periodically loaded traveling-wave parametric amplifiers using variable reactance diodes are described in detail.	R.C. Honey E.M.T. Jones
On Measurements of Microwave *E* and *A* Field Distributions by Using Modulated Scattering Methods	IRE Tr Micro T&T May 1960	The measurement of *H* field distribution by using a loop scatterer formed by two diodes is discussed.	Ming-Kuei Hu
Impulse Noise Reduction Circuit for Communications Receivers	IRE Tr Vehic Comm May 1960	System is suggested which consists of a gating signal generator a balanced gate which blocks the transmission during the gating period.	W.F. Chow
The Application of Semiconductors in a 860 MC Radio Receiver	IRE Tr Vehic Comm May 1960	An all-solid-state, FM radio receiver operating at 860 *mc* is described using transistors and variable reactance diodes.	L.G. Schimpf
Theory of a Negative-Resistance Transmission Line Amplifier with Distributed Noise Generators	Jl Appd Phys May 1960	Generalized treatment of a transmission line with distributed negative resistances.	K.K.N. Chang
On the Determination of the Intrinsic Equivalent Circuit Parameters of Drift Transistors	Jl Elecncs & Cont. May 1960	Methods of determining the "Effective" base resistance and collector capacitance of alloy-junction and diffused-type of graded base transistors are presented.	M.B. Das
Etching Behavior of the (110) and (100) Surfaces of InSb	Jl Electrochem Soc May 1960	Preferential and nonpreferential etching characteristics of the (110) and (100) surfaces of InSb are investigated.	H.C. Gatos M.C. Lavine
Characteristics of the (111) Surfaces of the III-V Intermetallic Compounds	Jl Electrochem Soc May 1960	Surface characteristics of the (111) crystallographic planes of the III-V intermetallic compounds are discussed.	H.C. Gatos M.C. Lavine
Growth and Heat Treatment of Zinc Sulfide Single Crystals	Jl Electrochem Soc May 1960	Zinc sulfide crystals grow readily from the vapor phase if small traces of certain impurities, such as zinc oxide and copper, are present.	A. Kremheller
Effect of CdS Addition in ZnS: Cu, In, and ZnS:Ag In Phosphors	Jl Electrochem Soc May 1960	Addition of CdS causes the ratio of intensities of the short to long wave-length emission to increase.	E.F. Apple
Polarization of Fluorescence in CdS and ZnS Single Crystals	Jl Electrochem Soc May 1960	Various symmetry properties of the wurtzite structure are discussed; the band structure of CdS and ZnS at k=000 is discussed.	J.L. Birman
Polarization of Luminscence in ZnS and CdS Single Crystals	Jl Electrochem Soc May 1960	The fluorescent emission form hexagonal ZnS and CdS single crystals is found to be polarized preferentially perpendicular to the c axis for both polarized and impolarized excitation.	A. Lempicki
Exciton Energy Levels in Germanium and Silicon	Jl Phys Chem Solids May 1960	The energies of the lowest-lying levels of the direct exciton in germanium, and the indirect excitons in Ge and Si have been calculated.	T.P. McLean R. Loudon
The Adsorption of Oxygen on Clean Silicon Surfaces	Jl Phys Chem Solids May 1960	The adsorption of oxygen or clean silicon surfaces produced by crushing in vacuo has been examined in the pressure range 30-200 μ Hg of oxygen at room temperature.	M. Green K.H. Maxwell
Solid Solution in A^{II} B^{VI} Tellurides	Jl Phys Chem Solids May 1960	Alloys have been produced for the three systems CdTe-HgTe, CdTe-ZnTe and HgTe-ZnTe, annealed to obtain equilibrium conditions.	J.C. Woolley B. Ray
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Determination of Numbers of Injected Holes and Electrons in Semiconductors	Philips Res Repts April 1960	It is shown how measurements of the photo Hall-effect and photoconduction may give information of Δn and Δp separately.	F. van der Maesen
Diffusion of Cadmium and Zinc in Gallium Arsenide	Physical Review May 15, 1960	The diffusion of Cd and Zn in GaAs has been studied by using radioactive isotopes of these elements as tracers.	B. Goldstein
Measurement of Lifetime In Ge From Noise	Physical Review May 15, 1960	The lifetime of the minority carrier may be obtained from a noise measurement in a method which consists of liberating hole electron pairs by light.	S. Okazaki H. Oki
Effects of Hydrostatic Pressure on the Piezoresistance of Semiconductors *i*-InSb, *p*-Ge, *p*-InSb and *n*-GaSb	Physical Review May 15, 1960	A method for measuring the piezoresistance of a sample under high hydrostatic pressure by comparison with the piezoresistance of intrinsic InSb is described.	R.W. Keyes M. Pollack
Rectification Without Injection at Metal-to-Semiconductor Contacts	Physical Review May 15, 1960	It is shown that strong rectification, whose direction depends only on the bulk type, may occur for such contacts to extrinsic, but no intrinsic, semiconductors.	N.J. Harrick
Zeeman Effect of Impurity Levels in Silicon	Physical Review May 15, 1960	Completely resolved Zeeman spectra for the bismuth donor in silicon, including optical transitions from the 1s donor to excitated states are presented.	S. Zwerdling K.J. Button B. Lax
Surface Transport in Semiconductors	Physical Review May 15, 1960	A transport theory is given for electrons and holes in space charge layers at semiconducting surfaces.	R.F. Greene D.R. Frankl J. Zemel
Frequency Factor and Energy Distribution of Shallow Traps in Cadmium Sulfide	Physical Review May 15, 1960	Current noise and photoconductivity measurements taken under uniform 5200A illumination on CdS single crystals are used to derive the above.	J.J. Brophy R. J. Robinson
Comparison of Gain, Bandwith, and Noise Figure of Variable-Reactance Amplifiers and Converters	Proc IEE (Br) May 1960	Formulae are derived; it is shown that for equal gains and noise figure the converter has greater bandwidth than the amplifier.	J.D. Pearson J.E. Hallett
Measurement of Transistor Characteristic Frequencies in the 20-1000 Mc/s Range	Proc IEE (Br) May 1960	Apparatus is described for the rapid determination of the cut-off frequencies, f, and $f\alpha$ of transistors in this range.	J. Bickley
The Input Impedance of Rectifier Modulators	Proc IEE (Br) May 1960	It is shown how the input impedance of a rectifier modulator of series, shunt, or ring-type, can be calculated.	D.G. Tucker

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Low-Noise Tunnel Diode Down Converter Having Conversion Gain	Proc IRE May 1960	An experimental UHF circuit converting from a signal frequency of 210 *mc* to an intermediate frequency of 30 *mc* is used to illustrate the feasibility of this new converter.	K.K.N. Chang G.H Geilmeier H.J. Prager
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Some Notes on the History of Parametric Transducers	Proc IRE May 1960	This paper summarizes briefly the chronology of the development of parametric transducers; includes bibliography.	W.W. Mumford
The Electron Theory of Metals	Res Appd in Ind (Br) May 1960	The modern theory is used to explain simple properties of semiconductors; theory of alloys.	B.L. Mordike
Microminiaturization of Electronic Equipment	Res Appd in Ind (Br) May 1960	Three systems of microminiaturization are described—micromodule, microcircuit and solid circuit.	G.W.A. Dummer
Application of Transistors to Video Equipment	Semiconductor Prods May 1960	Portable transistorized camera-transmitter circuitry is described.	K. Hiwatashi Et al
Esaki or Tunnel Diodes, Part 1	Semiconductor Prods May 1960	Discussion of physical effects which produce electrical characteristics; also, design and construction of these devices.	W.W. Gartner
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The Behavior of *p*- and *n*- Doped Contacts in a Space-Charge Depletion Region	SolidStateElecncs(Br) May 1960	A qualitative description of the floating potential and the forward and reverse characteristics of a reverse biased *p-n* junction is presented.	J.M. Lavine
Indium as a Source of Impurities in Indium Arsenide	SolidStateElecncs(Br) May 1960	Results show that a significant proportion of the donor impurities in the purest InAs now available may originate in the indium used for synthesis.	A.J. Strauss T.C. Harman E.B. Owens M.C. Finn
The Interpretation of the Stationary and Transient Behaviour of the Refrigeration Thermocouples.	SolidStateElecncs(Br) May 1960	The theory is presented in an improved form; the Thomson effect, the temperature variation of electrical resistance and surface heat transfers, all being taken into account.	J.E. Parrot
Radiation Limited PbS Cells	SolidStateElecncs(Br) May 1960	The noise of PbS chemically deposited cells has been measured in an excess-radiation atmosphere.	R.L. Williams
Minority Carrier Effects in Chemically Deposited PbS Photoconductive Films	SolidStateElecncs(Br) May 1960	Using the PEM and Hall effect it has been established that the minority carrier diffusion length is at least as large as the film thickness.	R.L. Williams
An All-Transistor PDM Telemetry Coder	US Govt Res Repts April 15 1960 LC $4.80 PB 144721	Description of coder that is very linear, and is unaffected by variations in signal voltage during the information pulse.	J. S. Sheriven
Industrial Preparedness Study on Transistors and Automatic Machinery for their Manufacture	US Govt Res Repts April 15 1960 LC $4.80 PB138094	Tentative specifications for the QC-117 transistor based on the Type 30 welded package are being discussed.	F. M. Dukat G. Freedman
Industrial Preparedness Study on Transistors and Automatic Machinery for their Manufacture	US Govt Res Repts April 15 1960 LC $4.80 PB138054	Results of QC-131 lifetime tests to 2000 hours indicate good shelf life characteristics and other parameters.	F. M. Dukat G. Freedman
Industrial Preparedness Study on Transistors and Automatic Machinery for their Manufacture	US Govt Res Repts April 15 1960 LC $3.30 PB138055	The reproducibility of boron-aluminum alloys for fused-junction LF silicon transistor (type QC-131) emitters was studied.	F. M. Dukat G. Freedman
Silicon Power Transistors (Devices 15 and 16)	US Govt Res Repts April 15 1960 LC $16.80 PB138052	Feasibility, both mechanical and electrical, has been demonstrated for Device 15 and for Device 16 to a modified specification.	F. M. Dukat G. Freedman
Silicon Video Amplifier (Device 25)	US Govt Res Repts April 15 1960 LC $6.30 PB138051	Quarterly report No. 1, 12 Sep-12 Dec 57, on Industrial Preparedness Study on Transistors.	J. Sardella A. Caggiano
Investigation of the Applications for Negative Resistance Diodes for Switching Circuits	US Govt Res Repts April 15 1960 LC $4.80 PB144426	Work accomplished included some multivibrator circuits using a tunnel diode and application of *p-n-p-n* diodes as core drivers.	A. W. Carlson R. E. McMahon
Dependence of Metal-to-Semiconductor Contact Resistance upon Contact Loading	US Govt Res Repts April 15 1960 LC $9.30 PB 144565	The spreading resistance has been shown to be modified by the injection of minority carriers at the contact.	A. L. Ward
High Presure Effects in Semiconductors; Interband Scattering in Germanium	US Govt Res Repts April 15 1960 LC $18.30 PB138445	Results of the measurement of the presure variation of the electrical conductivity of *n*-type germanium at several temperatures are presented.	M. I. Nathan
Solid State Division Annual Report for 1957	US Govt Res Repts April 15 1960 LC $7.80 PB145027	Most of the work was performed in the field of magnetism with emphasis also on semiconductors, primarily photo-effects and bulk properties of PbS, PbSe, PbTe and InAs.	R. Talley
Research on the Preparation of Pure Metals	US Govt Res Repts April 15 1960 LC $7.80 PB144572	In the preparation of pure gallium a promising approach has been developed which is centered on the preparation of lithium gallium hydride.	C. J. Marsel W. Brenner
Study of the Physical Chemistry and Metallurgy of Semiconducting Materials	US Govt Res Repts April 15 1960 OTS $1.00 PB161353	A method was developed for the deposition of crystalline bars of silicon on a tantalum filament in such a manner as to allow the filament to be pulled out of the bar.	K. E. Bean W. E. Metcalf R. J. Starks
Test Circuits for the Measurement of Transistor Current-Gain in the 0.1- to 200 MC Frequency Range	US Govt Res Repts April 15 1960 LC $3.30 PB 144665	Components and techniques used, and problems encountered are described.	G. N. Kambouris E. Hirschmann

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Use of Transistors in Heterodyne-Type Portable Frequency Meter AN/URM-32	U S Govt Res Repts May 13 1960 LC $6.30 PB 145336	Circuit studies to establish the feasibility of using transistors as active elements to produce or improve the electrical characteristics of frequency meter AN/URM-32.	A.B. Przedpelski
Methods of Purification of Metals and Intermetallic Compounds	U S Govt Res Repts May 13 1960 Ots $2.25 PB 161415	SiC, ThO_2, and ZrO_2, were studied to learn how impurities move in thermal gradients in potential materials for high temperature thermoelectric, thermionic, or photovoltaic generators.	S. Susman
Proceedings of The Annual Power Sources Conference	U S Govt Res Repts May 13 1960 LC $28.70 PB 145521	Sessions included were on space power: thermal energy conversion, nuclear energy sources, solar energy sources, etc.	Army Sig R&D Fort Monmouth
Transistorized Equipment For Measuring Transistor Frequency Response	U S Govt Res Repts May 13 1960 LC $3.30 PB 145138	The theory and operation of a transistorized equipment capable of measuring the frequency response of transistors is described.	B. Reich W. Orloff
Microwave Solid State Devices	U S Govt Res Repts May 13 1960 LC $6.30 PB 14494	Work on the spectra of Cr doped Al_2O_3 (Ruby), Cr doped $3BeO \cdot 6SiO_2$ (Emerald) and Co doped Al_2O_3 has been completed.	Bell Tel Labs
Microwave Solid State Devices	U S Govt Res Repts May 13 1960 LC $6.30 PB 144934	Noise temperature measurements have been made on a traveling wave maser preamplifier.	Bell Tel Labs
Application of Transistors To Frequency Meter FR 67 () /U And Manufacture of Experimental Models	U S Govt Res Repts May 13 1960 LC $9.30 PB 145260	Two complete frequency meters were manufactured and tested for conformance with all electrical specifications.	H. Chisholm R. Ellsworth R. Evans
Oscillator Performance of Transistors in the HF to UHF Range	U S Govt Res Repts May 13 1960 LC $9.30 PB 145270	An outline is given of the factors to be considered in the design and construction of high frequency transistor oscillators having optimal output efficiency.	W.M. Feist
A Sampling Pulse Oscilloscope Unit Transistorized, 'Spout'	U S Govt Res Repts May 13 1960 LC $7.80 PB 144706	A sampling pulse oscilloscope unit transistorized, 'SPOUT' capable of resolving repetitive pulses with rise times in the order of 1 microsecond was designed and built.	P. Emile Jr.
Utilizing An Electronic Computer To Optimize a Transistor NOR Circuit	U S Govt Res Repts May 13 1960	The accuracy which a transistor NOR circuit can be designed for minimum power dissipation has been increased by including an additional parameter not considered in a previous analysis.	E.L. Cox L.L. Hall
A Stable Direct Current Amplifier for a Photoelectric Photometer	U S Govt Res Repts May 13 1960 LC $6.30 PB 138497	Stability and simplicity are obtained by using balanced circuitry, silicon power rectifiers, and transistors.	C.F. Bohme F.J. Heyden
Silicon Transistor	U S Govt Res Repts May 13 1960 LC $12.30 PB 145192	Research and development of silicon for semiconductor devices, and on semiconductor devices, primarily transistors employing silicon.	J.S. O'Flaherty M. Cutler Et al
Optimum Two-Terminal Interstage Design for High Frequency Transistor Amplifier	U S Govt Res Repts May 13 1960 LC $10.80 PB 144821	The design of an optimum two-terminal interstage is treated. In transistor feedback amplifier design the most satisfactory interstage networks are two-terminal structures.	W.H. Ku H.J. Carlin
Fuzing Applications of the Four-Layer Diode	U S Govt Res Repts May 13 1960 LC $6.30 PB 144986	Its characteristics make the device of special interest for application to fuzing systems since it can perform both the operations of timing and energy switching.	D.J. Russell
Thermoelectricity	U S Govt Res Repts May 13 1960 LC $34.80 PB 145601	New materials and new methods of preparation indicate that a survey of thermoelectricity at this time is desirable, and holds out promise that the development of practical thermoelectric generators is possible.	H.E. Stauss
Thermoelectricity	U S Govt Res Repts May 13 1960 LC $9.30 PB 145602	The power to weigh ratios of TE generators; characteristics of thermoelements cooled by radiation; effect of increasing temperature upon efficiency; other considerations.	H.E. Stauss
Thermoelectricity	U S Govt Res Repts May 13 1960 LC $12.30 PB 145603	The progress on development of new materials is encouraging up to intermediate temperature levels.	H.E. Struss
Industrial Preparedness Study On Silicon Junction Crystal Diodes	U S Govt Res Repts May 13 1960 LC $24.80 PB 138096	The developmental history, design, construction, electrical characteristics, and pilot line manufacturing process, are discussed for the IN658 glass encapsulated, Si junction diode.	W.E. Harding M. Klein
Industrial Preparedness Study On Transistors And Automatic Machinery For Their Manufacture	U S Govt Res Repts May 13 1960 LC $12.30 PB 138050	The use of Sr-98 base coat required DC-4 silicone grease or other protective processing to eliminate the collector diode current (I_{co}) and the floating potential (V_{1f}) problems encountered in environmental testing.	F.M. Dukat G. Freedman
Physical Principles of Avalanche Transistor Pulse Circuits	U S Govt Res Repts May 13 1960 LC $4.80 PB 144811	A simple physical theory is developed which permits a calculation of the significant points of avalanche transistor transient behavior.	P.J. Hamilton J. Gibbons W. Shockley
The Fabrication of Silicon Carbide Junctions	U S Govt Res Repts May 13 1960 LC $3.30 PB 144974	It has been found possible to grow *p-n* junctions in silicon carbide by depositing a single crystal film from the vapor phase onto a silicon carbide seed.	K.M. Hargenrother
Research On Silicon Carbide Transistors	U S Govt Res Repts May 13 1960 LC $4.80 PB 144975	Boron-tin-platinum alloy was found to be promising for forming *p-n* junctions in *n*-type silicon carbide.	Westinghouse Elec. Corp.
Investigation of High Frequency Transistor Logic Circuit for Digital Application	U S Govt Res Repts May 13 1960 LC $16.80 PB 145166	A discussion of the design of a logic module employing junction transistors is given.	T. Wong
Industrial Preparedness Study On Diffused Semiconductor Devices	U S Govt Res Repts May 13 1960 LC $18.30 PB 145445	Problems encountered in the operations of diffusion, tab soldering, control of the prealloying base width, plating and high temperature whisker soldering in regard to the 4.3 *mc* silicon graded base device.	Philco Corp.
Industrial Preparedness Study On Diffused Semiconductor Devices	U S Govt Res Repts May 13 1960 LC $18.30 PB 145449	Germanium Program: Arsenic has replaced phosphorus as the diffusant for the germanium devices, making possible a 100% increase in the output of diffused germanium blanks.	Philco Corp.
Measuring the Switching Times of High Speed Transistors and Diodes	Western Elec Engr Apr 1960	A newly developed direct reading system is described, together with a brief discussion of switching time measurement technology.	L. J. Montone

CHARACTERISTICS CHART of NEW TRANSISTORS

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEIE— Associated Electrical Industries Ediswan Div.
AEIL— Associated Electrical Industries Export
BEN— Bendix Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS Electronics
CPC— C.P. Clare Transistor Corp.
CDLF— Compagnie des Lampes
CSF— Compagnie Generale
CRY— Crystalonics, Inc.
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
ETC— Electronic Transistor Corp.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thompson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HIVB— Hivac Ltd.
HITJ— Hitachi Ltd., Mushashi Works
HSD— Hoffman Semiconductor Div.
HUG— Hughes Aircraft Co.
IND— Industro Transistor Corp.
INTG— Intermetall
KOKJ— Kobe Kogyo Corp.
LCTF— Labortoire Central de Telecommunications
MIFI— Microfarad (Italy)
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NAC— National Semiconductor Corp.
NTLB— Newmarket Transistors Ltd.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Lansdale Division
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RADF— La Radiotechnique, Div. Tubes Electroniques
RHE— Rheem Semiconductor Corp.
ROSG— Dr. ing. Rudolph Rost
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SGSI— Societa General Semiconduttori
SONY— Sony Corp.
SPE— Sperry Rand Corporation
SPR— Sprague Electric Co.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
SYL— Sylvania Electric Products Inc.
TOSJ— Tokyo Shibaura Electric Co.
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments Incorporated
TIIB— Texas Instruments Ltd.
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WTC— Western Transistor Corp.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	Max. Ratings @ 25° C: DERATING °C/W	Max. Ratings @ 25° C: V_{CB}	Max. Ratings @ 25° C: V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Typical Characteristics: Gain: PARAMETER and (condition)	Typical Characteristics: Gain: VALUE	MFR. See code at start of charts
2G398	1	PNPA	Ge	50		105			h_{FE}:I_E-5.0ma	57min	SGSI
2N706B	5	NPNMe	Si	1000	150	25	20	400†	h_{FE}:I_C- 10ma	20-60	MOT
2N768	5	PNPMD	Ge	35	2100	12	10	125†∅	h_{FE}:I_C-2.0ma	40	PHI
2N769	5	PNPMD	Ge	35	2100	12	12	600†∅	h_{FE}:I_C- 20ma	55	PHI
2N770	5	NPND	Si	150	800	20	20	75†∅	h_{FE}:I_C- 20ma	25	PHI
2N771	5	NPND	Si	150	800	20	20	100†∅	h_{FE}:I_C- 20ma	50	PHI
2N772	5	NPND	Si	150	800	25	25	75†∅	h_{FE}:I_C- 10ma	35	PHI
2N773	4	NPND	Si	150	800	20	20		PG at 4.3Mc	25db	PHI
2N774	4	NPND	Si	150	800	20	20		h_{fe}:I_e-2.0ma	20	PHI
2N775	4	NPND	Si	150	800	20	20		h_{fe}:I_e-2.0ma	50	PHI
2N776	4	NPND	Si	150	800	20	20		PG at 12.5Mc	25db	PHI
2N777	4	NPND	Si	150	800	20	20		h_{fe}:I_e-2.0ma	20	PHI
2N778	4	NPND	Si	150	800	20	20		h_{fe}:I_e-2.0ma	50	PHI
2N1158	2	PNPMD	Ge	60	1250	20	20		PG at 200Mc	30mw	PHI
2N1158A	2	PNPMD	Ge	75	1000	20	20		PG at 100Mc	48mw	PHI
2N1162A	3	PNPA	Ge	90W	.80	50	35	4.0KcΔ	h_{FE}:I_C- 25A	15-65	MOT
2N1163A	3	PNPA	Ge	90W	.80	50	35	4.0KcΔ	h_{FE}:I_C- 25A	15-65	MOT
2N1164A	3	PNPA	Ge	90W	.80	80	60	4.0KcΔ	h_{FE}:I_C- 25A	15-65	MOT
2N1165A	3	PNPA	Ge	90W	.80	80	60	4.0KcΔ	h_{FE}:I_C- 25A	15-65	MOT
2N1166A	3	PNPA	Ge	90W	.80	100	75	4.0KcΔ	h_{FE}:I_C- 25A	15-65	MOT
2N1167A	3	PNPA	Ge	90W	.80	100	75	4.0KcΔ	h_{FE}:I_C- 25A	15-65	MOT
2N1199A	5	NPND	Si	150	800	20	20	75†∅	h_{FE}:I_C- 20ma	25	PHI
2N1474	2	NPNA	Si	250	600	60	60	1.5	h_{fe}:I -1.0ma	26	SPE
2N1474A	2	NPNA	Si	250	600	60	60	2.5	h_{fe}:I -1.0ma	30	SPE
2N1475	2	NPNA	Si	250	600	60	60	1.5	h_{fe}:I -1.0ma	60	SPE
2N1476	2	NPNA	Si	250	600	100	100	1.5*	h_{fe}:I -1.0ma	24	SPE
2N1477	2	NPNA	Si	250	600	100	100	1.5*	h_{fe}:I -1.0ma	45	SPE
2N1529A	3	PNPA	Ge	90W	.80	40	30	10KcΔ	h_{FE}:I_C-3.0A	20-40	MOT
2N1530A	3	PNPA	Ge	90W	.80	60	45	10KcΔ	h_{FE}:I_C-3.0A	20-40	MOT
2N1531A	3	PNPA	Ge	90W	.80	80	60	10KcΔ	h_{FE}:I_C-3.0A	20-40	MOT

NOTATIONS

Under Use

1- Low power a-f equal to or less than 50 mw
2- Medium power a-f 50 mw and equal to or less than 500 mw
3- Power 500 mw
4- r-f/i-f
5- Switching and Computer
6- Low Noise
7- Photo
8- Mixer
9- Local Oscillator
N- Revised Spec.
10- Chopper
11- Matched Pair

Under Gain Value

∅ - Pulsed

Under Type

A- Alloyed
D- Diffused or Drift
F- Fused
G- Grown
H- Hook Collector
M- Microalloy
PL- Planar
Me- Mesa
O- Other
S- Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ Tetrode

Under fab

* — Maximum Frequency
# — Figure of Merit
Δ — f_e
∅ — Minimum
† — f_T (Gain Bandwidth Product)
El — f_{os} max. (Max. freq. of oscillation)

Under Derating

∅ - Infinite heat sink

TYPE NO.	USE {See Code Below}	TYPE {See Code Below}	MAT	Max. Ratings @ 25° C: Pc (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	VALUE	MFR. See code at end of chart
2N1532A	3	PNPA	Ge	90W	.80	100	75	10Kc∆	$h_{FE}:I_C$-3.0A	20-40	MOT
2N1534A	3	PNPA	Ge	90W	.80	40	30	8.5Kc∆	$h_{FE}:I_C$-3.0A	35-70	MOT
2N1535A	3	PNPA	Ge	90W	.80	60	45	8.5Kc∆	$h_{FE}:I_C$-3.0A	35-70	MOT
2N1536A	3	PNPA	Ge	90W	.80	80	60	8.5Kc∆	$h_{FE}:I_C$-3.0A	35-70	MOT
2N1537A	3	PNPA	Ge	90W	.80	100	75	8.5Kc∆	$h_{FE}:I_C$-3.0A	35-70	MOT
2N1539A	3	PNPA	Ge	90W	.80	40	30	8.5Kc∆	$h_{FE}:I_C$-3.0A	50-100	MOT
2N1540A	3	PNPA	Ge	90W	.80	60	45	8.5Kc∆	$h_{FE}:I_C$-3.0A	50-100	MOT
2N1541A	3	PNPA	Ge	90W	.80	80	60	8.5Kc∆	$h_{FE}:I_C$-3.0A	50-100	MOT
2N1542A	3	PNPA	Ge	90W	.80	100	75	8.5Kc∆	$h_{FE}:I_C$-3.0A	50-100	MOT
2N1544A	3	PNPA	Ge	90W	.80	40	30	4.0Kc∆	$h_{FE}:I_C$-3.0A	75-150	MOT
2N1545A	3	PNPA	Ge	90W	.80	60	45	4.0Kc∆	$h_{FE}:I_C$-3.0A	75-150	MOT
2N1546A	3	PNPA	Ge	90W	.80	80	60	4.0Kc∆	$h_{FE}:I_C$-3.0A	75-150	MOT
2N1547A	3	PNPA	Ge	90W	.80	100	75	4.0Kc∆	$h_{FE}:I_C$-3.0A	75-150	MOT
2N1549A	3	PNPA	Ge	90W	.80	40	30	10Kc∆	$h_{FE}:I_C$- 10A	10-30	MOT
2N1550A	3	PNPA	Ge	90W	.80	60	45	10Kc∆	$h_{FE}:I_C$- 10A	10-30	MOT
2N1551A	3	PNPA	Ge	90W	.80	80	60	10Kc∆	$h_{FE}:I_C$- 10A	10-30	MOT
2N1552A	3	PNPA	Ge	90W	.80	100	75	10Kc∆	$h_{FE}:I_C$- 10A	10-30	MOT
2N1553A	3	PNPA	Ge	90W	.80	40	30	6.0Kc∆	$h_{FE}:I_C$- 10A	30-60	MOT
2N1554A	3	PNPA	Ge	90W	.80	60	45	6.0Kc∆	$h_{FE}:I_C$- 10A	30-60	MOT
2N1555A	3	PNPA	Ge	90W	.80	80	60	6.0Kc∆	$h_{FE}:I_C$- 10A	30-60	MOT
2N1556A	3	PNPA	Ge	90W	.80	100	75	6.0Kc∆	$h_{FE}:I_C$- 10A	30-60	MOT
2N1557A	3	PNPA	Ge	90W	.80	40	30	5.0Kc∆	$h_{FE}:I_C$- 10A	50-100	MOT
2N1558A	3	PNPA	Ge	90W	.80	60	45	5.0Kc∆	$h_{FE}:I_C$- 10A	50-100	MOT
2N1559A	3	PNPA	Ge	90W	.80	80	60	5.0Kc∆	$h_{FE}:I_C$- 10A	50-100	MOT
2N1560A	3	PNPA	Ge	90W	.80	100	75	5.0Kc∆	$h_{FE}:I_C$- 10A	50-100	MOT
2N1644	5	NPND	Si	600	250	60	5.0	50†	$h_{fe}:I_c$-150ma	80	FSC,HSD,RHE
2N1676	5	PNPD	Si	100	1200	4.5	4.5	16†Ø	offset volt.	1mv max	PHI
2N1677	5	PNPD	Si	100	1200	4.5	4.5	16†Ø	offset volt.	3mv max	PHI
2N1683	5	PNPD		150	400	13	12	80	$h_{FE}:I_C$- 40	85	RCA
2N1684	5	PNP		100	.75	25	20	8.0			SYL
2N1685	5	NPN		100	.75	25	20	10	$h_{FE}:I_C$-100ma	60	SYL
2N1711	3,4,5	NPNPl	Si	3000	58.3	60	40	200	$h_{FE}:I_C$-150ma	100-300	FSC,RH
2N1751	3,5	PNPDA	Ge	100W	.80	80	80		$h_{FE}:I_C$- 20A	60	BEN
AF111	2	PNPD	Ge	65		20	15	50			INTG
AF112	2	PNPD	Ge	65		20	15	60			INTG
AF113	2	PNPD	Ge	65		20	15	80			INTG
C106	5	PNPAY	Si	250	.54	30	10	1.2	$h_{fe}:I_b$-.10ma	40	CRY
HA9500	5	D	Si	750		40	30		$h_{FE}:I_C$-150ma	15-45	HUG
HA9501	5	D	Si	750		40	30		$h_{FE}:I_C$-150ma	30-90	HUG
HA9502	5	D	Si	750		50	50		$h_{FE}:I_C$-150ma	25-100	HUG
MA1	2,4	PNPA	Ge	25		6.0	6.0	20⊠Ø	$h_{fe}:I_c$-1.0ma	40-450	SPR
MA2	2,4	PNPA	Ge	20		3.0	3.0	20⊠Ø	$h_{fe}:I_c$-1.0ma	40-450	SPR
OC303	2	PNP	Ge	67.5		15	15	.75	h_{FE}:	20-35	INTG
OC304/1	2	PNP	Ge	67.5		15	15	.90	h_{FE}:	30-50	INTG
OC304/2	2	PNP	Ge	67.5		15	15	.90	h_{FE}:	50-80	INTG
OC304/3	2	PNP	Ge	67.5		15	15	.90	h_{FE}:	80-120	INTG
OC305/1	2	PNP	Ge	67.5		8.0	8.0	2.0	h_{FE}:	120-200	INTG
OC305/2	2	PNP	Ge	67.5		8.0	8.0	2.0	h_{FE}:	200min	INTG
OC306/1	2	PNP	Ge	67.5		15	15	.90	h_{FE}:	30-50	INTG
OC306/2	2	PNP	Ge	67.5		15	15	.90	h_{FE}:	50-80	INTG
OC306/3	2	PNP	Ge	67.5		15	15	90	h_{FE}:	80-120	INTG
OC307	2,11	PNP	Ge	100		35	32	12K	$h_{FE}:I_C$-125ma	25min	INTG
OC308	2,11	PNP	Ge	100		35	32	12K	$h_{FE}:I_C$- 80ma	60	INTG
OC309	2,11	PNP	Ge	100		60	60		$h_{FE}:I_C$-125ma	25min	INTG
OC318	2,11	PNP	Ge	330		20	20		$h_{FE}:I_C$-300ma	66	INTG

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Under Gain Value

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Under Type

A- Alloyed
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H- Hook Collector
M- Microalloy
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Me- Mesa
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Y - Symmetrical
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Under fab

* — Maximum Frequency
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Under Derating

Ø - Infinite heat sink

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	MFR. See code at start of charts
OC330	1	PNP	Ge	45		15	15	.80	h_{FE}:	20-35	INTG
OC331	1	PNP	Ge	30			7.0	1.2	h_{FE}:	20-35	INTG
OC340	1	PNP	Ge	45		15	15	1.1	h_{FE}:	30-120	INTG
OC341	1	PNP	Ge	30			7.0	1.2	h_{FE}:	30-50	INTG
OC342	1	PNP	Ge	30			7.0	1.2	h_{FE}:	50-80	INTG
OC343	1	PNP	Ge	30			7.0	1.2	h_{FE}:	80-120	INTG
OC350	1	PNP	Ge	45		10	8.0	2.0	h_{FE}:	120min	INTG
OC351	1	PNP	Ge	30			7.0	2.0	h_{FE}:	120min	INTG
OC360	1	PNP	Ge	45		15	15	.80	h_{FE}:	20min	INTG
OC361	1	PNP	Ge	30			7.0	1.2	h_{FE}:	30-50	INTG
OC362	1	PNP	Ge	30			7.0	1.2	h_{FE}:	50-80	INTG
OC363	1	PNP	Ge	30			7.0	1.2	h_{FE}:	80-120	INTG
OC390	2	PNP	Ge	65		15	6.0	4.5	h_{FE}:	40	INTG
OC400	2	PNP	Ge	65		15	6.0	7.0	h_{FE}:	75	INTG
OC410	2	PNP	Ge	65		15	6.0	12	h_{FE}:	110	INTG
OC430	2	PNP	Si	300		10	10	20∅	h_{FE}:	10-20	INTG
OC440	2	PNP	Si	300		30	30	20∅	h_{FE}:	10-20	INTG
OC445	2	PNP	Si	300		50	50	20∅	h_{FE}:	10-20	INTG
OC450	2	PNP	Si	300		75	75	20∅	h_{FE}:	20	INTG
OC460	2	PNP	Si	300		10	10	20∅	h_{FE}:	30	INTG
OC463	2	PNP	Si	300		10	10	20∅	h_{FE}:	30	INTG
OC465	2	PNP	Si	300		20	20	20∅	h_{FE}:	30	INTG
OC466	2	PNP	Si	300		10	10	20∅	h_{FE}:	30	INTG
OC468	2	PNP	Si	300		10	10	20∅	h_{FE}:	40min	INTG
OC469	2	PNP	Si	300		32	32	20∅	h_{FE}:	10min	INTG
OC470	2	PNP	Si	300		30	30	20∅	h_{FE}:	30	INTG
OC480	2	PNP	Si	300		125	125	20∅	h_{FE}:	20	INTG
OD650	3	PNPA	Ge	45W	1.0	60	25	.10	h_{FE}:I_C- 15A	10min	AEG
OD650B	3	PNPA	Ge	45W	1.0	60	25	.10	h_{FE}:I_C-5.0A	15min	AEG
OD651	3	PNPA	Ge	45W	1.0	60	40	.10	h_{FE}:I_C- 15A	10min	AEG
OD651A	3	PNPA	Ge	45W	1.0	60	30	.10	h_{FE}:I_C- 15A	10min	AEG
OD652	3	PNPA	Ge	45W	1.0	60	15	.10	h_{FE}:I_C- 30A	10min	AEG
PT822	3,4,5	D	Si	2800	55	80	50	175	h_{FE}:I_C-150ma	75	PSI
PT851	3,4,5	D	Si	2800	55	45	30	175	h_{FE}:I_C-100ma	90	PSI
PT852	3,4,5	D	Si	2800	55	45	30	175	h_{FE}:I_C-100ma	25	PSI
PT853	3,4,5	D	Si	2400	63	25	20	175	h_{FE}:I_C-150ma	12	PSI
RT697M	5	NPND	Si	3000	50	60	50	90†	h_{FE}:I_C-150ma	40-120	RHE
SO1	2,4	PNPS	Ge	20		5.0	5.0	20∅∅	h_{fe}:I_C-.50ma	10min	SPR
SO2	2,4	PNPS	Ge	15		3.0	3.0	10∅∅	h_{fe}:I_C-.50ma	10min	SPR
SO3	2,4	PNPS	Ge	20		5.0	5.0	30∅∅	h_{fe}:I_C-.50ma	10min	SPR
TK44C	2	NPNA	Ge	150	.30	60	40	.50∅	h_{FE}:I_C- 80ma	30min	STCB
XA111	4	PNPA	Ge	120	330	20	16	5.0	h_{fe}:I_C-1.0ma	35	AEIE
XA112	4	PNPA	Ge	120	330	20	16	8.0	h_{fe}:I_C-1.0ma	60	AEIE
XB113	2	PNPA	Ge	150	330	35	16		h_{FE}:I_C- 50ma	47	AEIE
XC171	3	PNPA	Ge	750	65	26	16		h_{FE}:I_C-400ma	72	AEIE
WX115UA	3,5	NPNA	Si	250W	.45	50	50	.20	h_{FE}:I_C- 10A	10	WEST
WX115UB	3,5	NPNA	Si	250W	.45	100	100	.20	h_{FE}:I_C- 10A	10	WEST
WX115UC	3,5	NPNA	Si	250W	.45	150	100	.20	h_{FE}:I_C- 10A	10	WEST
WX115UD	3,5	NPNA	Si	250W	.45	200	200	.20	h_{FE}:I_C- 10A	10	WEST
WX115WA	3,5	NPNA	Si	250W	.45	50	50	.20	h_{FE}:I_C- 15A	10	WEST
WX115WB	3,5	NPNA	Si	250W	.45	100	100	.20	h_{FE}:I_C- 15A	10	WEST
WX115WC	3,5	NPNA	Si	250W	.45	150	150	.20	h_{FE}:I_C- 15A	10	WEST
WX115XA	3,5	NPNA	Si	250W	.45	50	50	.20	h_{FE}:I_C- 20A	10	WEST
WX115XB	3,5	NPNA	Si	250W	.45	100	100	.20	h_{FE}:I_C- 20A	10	WEST

PREVIOUSLY REGISTERED NEWLY ANNOUNCED TRANSISTORS:

BENDIX: 2N307, 2N307A, 2N255, 2N256

CBS ELECTRONICS: 2N173, 2N174, 2N277, 2N278, 2N441, 2N442, 2N443, 2N1100

INTERMETALL: 2N257, 2N268, CTP1108, CTP1109, CTP1111

MOTOROLA SEMICONDUCTOR: 2N173, 2N174, 2N277, 2N278, 2N441, 2N442, 2N443, 2N1099, 2N1100, 2N1358

NATIONAL SEMICONDUCTOR: 2N243, 2N244, 2N339 thru 2N343, 2N473, 2N474, 2N474A, 2N475 thru 2N479, 2N480A, 2N497, 2N498, 2N541, 2N542, 2N543, 2N656, 2N657, 2N698, 2N706A, 2N719, 2N753, 2N1149/903, 2N1150/904, 2N1151/904A, 2N1152/905, 2N1153/910, 2N1154/951, 2N1155/952, 2N1156/953, 2N1247, 2N1248, 2N1276 thru 2N1279

PACIFIC SEMICONDUCTORS: 2N698, 2N699, 2N706, 2N1420

RCA: 2N706, 2N706A

RHEEM SEMICONDUCTOR: 2N698, 2N702, 2N703, 2N705, 2N706, 2N706A, 2N706B, 2N707, 2N710, 2N715, 2N716, 2N717, 2N720, 2N730, 2N731, 2N734, 2N736, 2N1409, 2N1410, 2N1564, 2N1565, 2N1566

SPERRY SEMICONDUCTOR: 2N696, 2N697, 2N699, 2N706, 2N1118, 2N1118A, 2N1119

SPRAGUE: 2N501A, 2N588

Industry News . . .

CONFERENCE CALENDAR

The Following December 1960 Meetings Are Scheduled:

Nov 30–Dec 2 — 18th Annual Electric Furnace Committee Conference, Morrison Hotel, Chicago. Sponsored by Iron & Steel Division, Metallurgical Society of AIME. For information: The Metallurgical Society of AIME, 29 W. 39th St., N.Y. 18, N.Y.

Dec 1-2 — PGVC Annual Meeting (Professional Group on Vehicular Communications), Sheraton Hotel, Philadelphia. Sponsored by PGVC. For information: W. G. Chaney, A T & T, 195 Bwy., N.Y. 7, N.Y., Room 1750.

Dec 12-14 — URSI-IRE "Fall Meeting," NBS Boulder Labs., Boulder, Colo. Sponsored by URSI, PGAP, PGI, PGCT, PGIT, PGMTT. For information: A. H. Shapely, CRPL Natl. Bureau of Standards, Boulder, Colo.

Dec 12-14 — American Nuclear Society Winter Meeting, Mark Hopkins Hotel, San Francisco.

Dec 13-15 — Eastern Joint Computer Conference, New Yorker Hotel & Manhattan Center, N.Y. Sponsored by PGEC, AIEE, ACM. For information: Elmer Kubie, Computer Usage Co., 18 E. 41 St., New York 17, N. Y.

Dec 14-16 — Atomic Industrial Forum Annual Conference, Fairmount Hotel, San Francisco.

Dec 26-30 — AAAS Annual Exposition of Science and Industry 127th Meeting, Biltmore Hotel, N.Y.C.

Dec 29-31 — American Physical Society Meeting, Berkeley, California.

RESEARCH & DEVELOPMENT

More than 800 scientists and engineers from industry, universities, and government participated in a Conference on Standards and Electronic Measurements held recently at the Bureau's Boulder (Colo.) Laboratories. Sponsored by the American Institute of Electrical Engineers, the Institute of Radio Engineers, and the National Bureau of Standards, the three-day meeting provided an opportunity for the exchange of information and ideas concerning the most recent developments in the field of electronics and measurements. The following are some of the reports presented during the various technical sessions.

A status report on frequency and time signals was presented by F. G. Merrill (Bell Telephone Laboratories, Inc.—N.J.), which outlined the differences and difficulties encountered in maintaining frequency standards by atomic beam devices, alkali vapor frequency standards, crystal oscillators of special design and with transistor circuitry, and synchronization of time and frequency over great distances.

W. L. Smith (Bell Telephone Laboratories—Whippany, N.J.) presented the results of work on crystal-controlled transistor oscillator circuits empolying precision AT-cut quartz resonators. These transistor oscillators provide short-term frequency stability comparable to vacuum-tube frequency-standard oscillators and are considerably reduced in size and power-drain.

J. R. Seifert and G. L. Allerton (Western Electric Company—Allentown, Pa.) have developed a new approach to the measurement of volume resistivity of semiconductor material at X-band frequencies. This measurement is usually made by sending a direct current through a sample of the material and measuring the voltage drop across two points on the surface of the material. The proposed advance consists of conducting this measurement with a high frequency test signal and using test samples to load the transmission system to determine the resistivity of limited areas and depths of material.

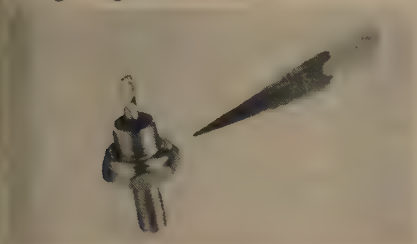
R. C. Powell and A. L. Rasmussen (NBS-Boulder) reported on a radio-frequency permittimeter, a new instrument, that shows complex conductivities differing considerably from those previously observed by other methods for ferrites and strong electrolytic solutions. The design embodies a coaxial radio frequency impedance transformer in which the secondary is a single turn of the material to be measured. This instrument is used with two terminal impedance bridges to determine the complex permittivity or complex conductivity of low-impedance materials. As no electrodes are needed, many conductors, semiconductors, electrolytes and high permittivity materials can be evaluated to about one percent. Errors due to electrode impedance and interaction, as well as first order series inductance, are eliminated.

R. P. Baker (Sandia Corp.), and J. Nagy, Jr. (Daystrom, Inc.) challenged the use of conventional standard cells as references. They offered precise electrical measurements by use of Zener diodes; these diodes have been investigated for use as standards in a militarized test set capable of operating many months without recalibration. Criteria for test methods and selection of diodes were established with respect to temperature coefficient, noise, and long-term stability. Improvements in these characteristics by matching and pairing and selection of operating conditions were considered. Using a second Zener reference in the test set provides a reference current for standardization of an *ac-dc* transfer device and provides a self-checking circuit which greatly increases reliability.

Norton Company, Worcester, Mass., recently announced the development of a new high temperature refractory product, known as CRYSTOLON "63," which is expected to have wide application as a relatively low cost structural ceramic, high in physical strength and resistance to attack by heat and molten salt.

New Products

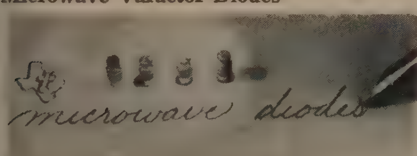
Voltage Regulator Diodes



10-watt Voltage Regulator Diodes with sharp Zener characteristics and extremely low dynamic impedances are available from General Instrument Semiconductor Division. Types IN1808, IN2044 through IN2049, and IN1351 through IN1362, have silicon diffused junctions for high uniformity of electrical characteristics. These diodes provide excellent voltage regulation covering the range from 7.5 to 30 volts with ±10% tolerance on standard types and ±5% on "A" versions of the standard types offered. Operating temperatures range up to 175°C.

Circle 151 on Reader Service Card

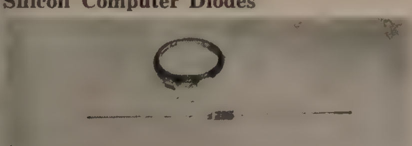
Microwave Varactor Diodes



TI announced recently that it has established a new ceiling on the high-frequency capabilities of diodes by adding three new device types—XD-501, 502, and 503, to its line of diffused gallium arsenide mesa microwave varactor diodes. XD-503 is rated for a Minimum Cutoff Frequency at Breakdown of 310 kmc. At $V_R = -2$ v, minimum cutoff frequencies of XD-500-503 are rated at 60, 81, 108, and 144 kmc, respectively. Total capacitance range is 0.5 μμf min to 1.4 μμf max and series inductance is 0.7 mμh at 9.4 kmc.

Circle 152 on Reader Service Card

Silicon Computer Diodes



Three silicon computer diodes featuring quick recovery and excellent operating stability at temperatures as high as 150°C have been introduced by Hoffman Semiconductor Division. Encased in a 400 milliwatt package, the diodes reach switching speeds of 0.3 microseconds.

Maximum peak inverse voltage is 50 volts for the 1N659, 100 volts for the 1N660 and 200 volts for the 1N661. Minimum Zener voltage at 100°C is 55 volts, 110 volts, and 220 volts respectively.

Circle 153 on Reader Service Card

Military Power Transistor

A new Military *p-n-p* Germanium Power Transistor, JAN-2N158, has been announced by CBS Electronics. Maximum ratings at 25°C are: −60 volts collector-to-emitter voltage, 2 amperes emitter current, 17 watts dissipation, and −65 to +85°C storage junction temperature range. The transistor features a minimum current gain of 21 and a maximum input voltage of 0.85 volt for an Ic of 0.5 ampere and a V_{CE} of −2 volts. Saturation voltage V_{CE} (sat) is only 0.75 volt at an Ic of 1 ampere and an Ib of 150 milliamperes. Thermal resistance (junction to case) is 3.5°C per watt.

Circle 155 on Reader Service Card

Oscilloscope

Operating with low-cost signal-amplifier and time-base plug-in units, Tektronix Type 560 Oscilloscope is basically an indicator. It contains a 5-inch crt with 3.5 kv accelerating potential, an 8 x 10 cm viewing area, an amplitude and sweep-time calibrator, and a regulated *d-c* supply providing 30 watts of power. The indicator accepts any two of four presently available plug-in units—which drive the crt deflection plates directly. Dimensions are 13½" high by 9¾" wide by 21½" deep. Weight is less than 27 pounds.

Circle 150 on Reader Service Card

Active Solid-State Materials

Active solid-state materials up to 99.9999+% pure are now being produced by a manufacturing firm with facilities devoted entirely to turning out such products, the newly created Chemical Products Division of Alloys Unlimited, Inc. Among the intermetallic compounds being produced are gallium arsenide, indium arsenide, gallium antimonide and indium antimonide. These are available in the form of large grain, polycrystalline ingots. Cadmium telluride, bismuth telluride, lead telluride and mercury telluride are available in the form of microcrystalline powders or polycrystalline ingots.

Circle 181 on Reader Service Card

Stainless Steel Glove Box

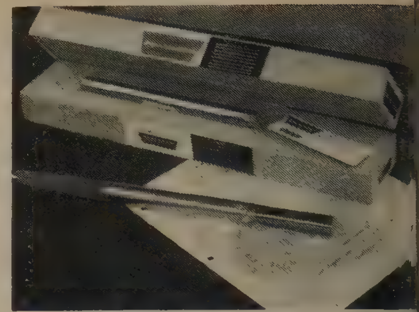
Delta Design, Inc. has recently introduced a dust tight, stainless steel glove box, Model B-10. The chamber can be used to provide dust free or dry air atmosphere, and to confine toxic or radioactive materials. Work space is 34" wide by 22" deep, with a maximum height of 22". A large sloping 10" by 28" safety plate glass window assures clear visibility Two 8" glove ports below the window are provided with cover plates.

Circle 174 on Reader Service Card

(continued on page 50)

New Products
(from page 47)

Single Crystal Silicon



Single crystal high purity silicon is being produced by Dow Corning. Resistivity and lifetime profiles indicate uniform characteristics over the entire length of each crystal, and from crystal to crystal, according to the company which are expected to result in increased yield of quality semiconductor devices, especially power rectifiers, diodes and *p-n-p-n* switches. Available in various diameters to 26 mm (approx. 1") and lengths to 350 mm (13¾") undoped *P* type single crystals have less than 0.15 parts per billion of boron; greater than 1000 ohm centimeters; minority carrier lifetime greater than 400 microseconds.

Circle 154 on Reader Service Card

Thermal Resistance Tester

Precise measurement of the thermal resistance of any semiconductor power diode or transistor is now made possible by a new instrument announced by Wallson Associates, Inc. Model 149 Thermal Resistance Tester utilizes the forward voltage drop at a constant low-level metering current to measure junction temperature. Heating current is 1-5, 1-50 amps; measuring current is 1-100 ma; measuring pulse width is 100 microseconds; cooling time is 650 microseconds max.; sampling rate is 10/second.

Circle 177 on Reader Service Card

Portable Transistor Analyzer

Hickok Electrical Instrument Company has introduced a new, portable transistor analyzer, Model 850P. Containing all of the operating features of the Model 850 formerly in this line, this new model comes in portable carrying case to facilitate its movement to different locations in the laboratory. It is claimed to be ideal when used as a breadboard in transistor experimentation to determine the operating characteristics of a transistor in varying situations. It measures parameters in any of three configurations: Common Base, Common Emitter, and Common Collector.

Circle 160 on Reader Service Card

Self Contained Portable Furnace

Those finding need for a general-purpose furnace that may be readily moved about and at the same time operate at higher temperatures will find the recently announced Pereco Series FGKS Electric Furnace of special interest. Pereny Equipment Company states that the unit is suited to all areas of heat-treating (metal or ceramics) calling for sustained temperatures up to 2900° F in normally oxidizing atmospheres. It incorporates molybdenum disilicide (Kanthal Super) elements for providing the sustained high operating temperatures. Power rating is 26KW 220/60/1.

Circle 176 on Reader Service Card

Germanium-Indium-Gallium Materials

Up to 5% germanium, alloyed with indium-gallium and fabricated into foil and preforms for semiconductor devices, is being produced by Alpha Metals, Inc. The resulting ternary alloys are available in the following forms and sizes: Spheres from .005"; tolerances are as close as .001". Foil from .0005" thin. Discs range upward from .005". Rectangles from .040" to .015". Squares start at .020". Washers may be had with a .020" i.d. and a land area as small as .005".

Circle 157 on Reader Service Card

Infrared Detector

Philco's Lansdale Division has announced the commercial availability of what they claim to be industry's highest sensitivity photo-voltaic infrared detector. The ISC-301 series of indium antimonide detectors are sensitive enough to spot a lighted cigarette 500 miles away at night when using only a one meter reflector, according to the company. More meaningful to infrared engineers is the demonstrated sensitivity represented by a D* of 15 x 10^9 for the top rated detector of the series, the ISC-301D.

Circle 182 on Reader Service Card

Germanium Alloy Junction Transistors

Two series of germanium alloy junction transistors designed for use in computers at increasing frequencies have been announced by Sylvania. They consist of 4 *n-p-n* types, 2N1302-1308; and 4 *p-n-p* types, 2N1303-1309. All 8 units have the following maximum ratings: collector to base voltage 25V, emitter to base voltage 25V, collector current 300 MA, power dissipation in free air 150 MW, temperature range −65°C to +100°C.

Circle 161 on Reader Service Card

Vacuum-Atmosphere Unit

A self-contained complete package unit for processing small parts in a vacuum or protective atmosphere has been announced by Lindberg Engineering Company. The unit consists of a furnace equipped with all electrical components and automatic controller; 4" I.D. special alloy retort for operation to 2250°F at a vacuum level of 0.5 micron, complete with water-jacketed cooling chamber; vacuum pumping system complete with all controls and vacuum gauge.

Circle 156 on Reader Service Card

New Literature

American Vulcathene, Division of The Nalge Co., Inc. has issued a catalog describing their line of "Vulcathene" non-corrosive drainline. Catalog fully describes and illustrates this completely integrated drainline system, which includes pipe, fittings, traps and sinks, and is made of polyethylene. Full details are given with regard to installation, applications, advantages over other systems, etc.

Circle 100 on Reader Service Card

The Nalge Co., Inc., has issued Catalog H459 (revised), "Plastic Laboratory Apparatus," describing their line of "Nalgene" plastics for science and industry. Includes illustrations and descriptions of plastic pipets, beakers, bottles, buckets and many other products, as well as a chemical resistance chart. A handy index lists the numerous items alphabetically.

Circle 101 on Reader Service Card

Ultra-miniature solid-electrolyte Tantalex Capacitors offer many advantages to the designer of hearing aids and other ultra-miniature circuits. Since no liquid electrolyte is used, there can be no leakage of liquid to damage miniature equipment. Further, they provide maximum capacitance per unit volume. The 'A' issue of Sprague Engineering Bulletin No. 3513 lists current standard production ratings for these ultra-miniature capacitors. In addition to the conventional dual-ended tubular design, it includes single-ended units for use in cramped locations. These capacitors can many times simplify the layout of printed wiring boards.

Circle 102 on Reader Service Card

A revised brochure, "General Plate Products," 4th edition, 14 pp., describes the scope of Texas Instruments' Metals & Controls Div., line including solid and clad base metals, solid and clad precious metals, thermostat metals, electrical contacts and the company's "industrial" metals: manganese age-hardening alloys, cored and clad wires, thin gauge metals, solid and clad reactor metals, clad metals for semiconductor applications and aluminum-iron alloys.

Circle 103 on Reader Service Card

The physical properties of gold-germanium, gold-silicon and gold-antimony alloys are described in a series of technical data sheets available from Alpha Metals, Inc., high purity metals fabricators. Designed for semiconductor engineers, each of these "Semiconductor Materials Data Sheets" contains a phase diagram of one of the foregoing alloys, a thorough description of its phase relationship and crystal structure, alloy properties and fabrication possibilities.

Circle 104 on Reader Service Card

Fish-Schurman Corporation has issued their latest FS STEELSET catalog DG 395 effective July 1, 1960. In it are described the large variety of metal-bonded diamond-impregnated products manufactured by the company. Included are drills, wheels, blades, dressers, hones, laps.

Circle 110 on Reader Service Card

Lourdes Instrument Corp., a division of Labline, Inc., has announced publication of a completely new and up-dated catalog on its full line of centrifuges and homogenizers. The catalog is a 16-page, fully illustrated book designed to offer finger-tip reference to the complete line manufactured by Lourdes. It also lists in detail the rotors and attachments produced for each model. Refrigerated and non-refrigerated models are shown, as well as vacuum and non-vacuum centrifuges.

Circle 105 on Reader Service Card

A bulletin sheet describing their newly designed Dual-Column Demineralizer is now available from the Penfield Manufacturing Co. Model UL-90, with a flow rate of 100 GPH, produces high purity water at a chemical cost of pennies. Its exceptionally compact design enables location any place in the plant. Columns of polished cast acrylic give the operator a clear view of the unit's operation at all times.

Circle 106 on Reader Service Card

Available from Fairchild Semiconductor Corp., is Technical Paper No. 10, "Status Report on Micrologic Elements" presented at the 51st Bumblebee Guidance Panel in New York, and "Status Report on Micrologic Element Development," which was also distributed at the WESCON Show in Los Angeles.

Circle 107 on Reader Service Card

A new twenty-page catalog detailing the complete and current product line of the Semiconductor Division of Hoffman Electronics Corporation is immediately available to all semiconductor users. The catalog, which is three-hole punched for convenient filing, contains electrical and physical parameters of the company's Silicon Solar Devices, Silicon Transistors, Silicon Diodes, Silicon Controlled Rectifiers, Zener Regulators and Zener Reference devices. Also included for user reference are current listings of all Hoffman Semiconductor Field Sales Offices and authorized Industrial Distributors.

Circle 108 on Reader Service Card

An all-new bulletin, covering S. S. White Industrial Airbrasive Units, provides detailed information on improved cutting techniques, new applications, new performance charts, new cutting powders, and new accessories for this cutting tool. Some examples of Airbrasive uses are demonstrated, such as cutting and cleaning semiconductor materials, and adjusting micromodule elements.

Circle 109 on Reader Service Card

INDEX TO ADVERTISERS

For reference purposes, the advertisers index includes all regular advertisers who have run within the current contract year. Those advertisers who appear in this issue are indicated by the page number adjacent to their listing, and are shown in a bold-face type.

INDEX TO ADVERTISERS

(Continued)

SOLID-ELECTROLYTE TANTALEX® CAPACITORS

prompt delivery and complete ratings from SPRAGUE

This solid-electrolyte Tantal Capacitor (shown 1½ times act size) is rated at 4.7 μF, 10 vo d-c, and is only ⅛" in diame by ¼" long.

Sprague, the pioneer in the production of solid-electrolyte tantalum electrolytic capacitors, now offers prompt delivery on production quantities of all standard ratings. New expanded facilities end production delays in your assembly of minified transistor circuits.

Typical of these Tantalex Capacitors is the Type 150D shown above. Its tiny sintered anode is impregnated with a solid, non-corrosive, semi-conductor material which cannot leak under any circumstance. It combines true miniaturization with electrical stability previously unobtainable in an electrolytic capacitor of any type.

Thermal coefficient of these capacitors is sufficiently low and linear so that for the first time a circuit designer can think of an electrolytic in terms of parts per million capacitance change. Nominal value is +500 ppm/°C. The capacitor may be used without derating over a range from −80°C to +85°C, or to 125 °C with appropriate derating, a temperature at which no other electrolytic has proved useful.

Solid construction permits the Type 150D to withstand the severe shock and vibration encountered in missile and ballistic applications. Hermetic sealing makes it completely immune to humid atmospheric conditions.

Complete performance data covering the wide range of sizes and ratings are in Engineering Bulletin 3520D, available on letterhead request to the Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

★ ★ ★

You can get off-the-shelf delivery at factory prices on pilot quantities up to 499 pieces from your local Sprague Industrial Distributor.

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